

# Computer Science

## University of Twente



Interim Research assessment  
2003-2005

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Computer Science  
University of Twente  
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## INTRODUCTION

We are pleased to present the Interim Research Assessment Report 2003-2005 of the Department of Computer Science (CS), Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS), University of Twente (UT).

This report primarily serves as a source of information for the 2007 Interim Research Assessment Committee for Computer Science at the three technical universities in the Netherlands. The report also provides information for others interested in our research activities.

The report consists of two parts: part A describes the department as a whole (institute in the terminology of the review protocol). Part B describes the ongoing research in the research groups of the Department of Computer Science. A list of peer-reviewed publications in international journals and in the proceedings of the major conferences concludes each section of part B. The structure of all sections is as agreed upon by the three technical universities in the review protocol.

Since the previous research assessment the organization of the university has changed considerably. The University of Twente has decided to reduce the number of faculties by merging previously independent faculties into a smaller number of new faculties. Computer Science is now a department within the EEMCS Faculty. At the start of the reporting period, the majority of the research was already organized in university wide, interdisciplinary research institutes. Coinciding with the reduction of the number of faculties the role of the research institutes has become more important. All Computer Science research is embedded in the Centre for Telematics and Information Technology (CTIT). At 3TU level a similar movement is in progress. Currently all Computer Science groups are represented in the 3TU Centre of Competence NIRICT, whereas three research groups are also part of the 3TU Centre of Excellence CeDICT. This organizational structure is explained in more detail in part A of the report. Research is a dynamic process. As this report appears, new developments are already underway. The report describes the state of affairs on 31 December 2006.

We hope that you will find the information you are looking for in this report. For the most recent information we invite you to visit our faculty web site: <http://www.eemcs.utwente.nl/> or the web site of our research institute <http://www.ctit.utwente.nl/> .

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**Section A: Documentation of the Research in the Department of Computer Science, Faculty of EEMCS, University of Twente, period 2003-2005**

The 'Institute', referred to by the terminology used in the "Standard Evaluation Protocol 2003-2009 for Public Research Organizations"<sup>1</sup>, is the Department of Computer Science of the Faculty of Electrical Engineering, Mathematics, and Computer Science, University of Twente. The Department is organized into research groups (chairs), each covering a coherent part in the broad field of Computer Science. In each research group, one or more 'Research Programs', in the terms used in the Protocol, are carried out. In Twente these programs are carried out within the framework of multidisciplinary research institutes. The term 'institute' here has a different meaning from the term used in the reporting under this protocol. A research institute in Twente is an institute at University level of which the Centre for Telematics and Information Technology (CTIT) includes all of Computer Science as well as research groups from Electrical Engineering, Mathematics, and other faculties. At 3TU level all Computer Science groups are represented in the 3TU Centre of Competence NIRICT. Computer Science does not play a role in the remaining institutes, such as MESA+ and BMTI. These institutes are not assessed here, although their influence university-wide on research policy is evident. Research programs of research groups participating in our research institutes fall under the formal responsibility of the Scientific Director of the Institute. This formal responsibility, of course, does not reduce the responsibilities of the group leaders (chair holders) for the research activities carried out in the research group.

The Department of Computer Science has celebrated its 25th anniversary in September 2006. Computer Science began life as a teaching activity. However, in the last 5 years of its existence, the department has finished its evolution towards achieving a healthy balance between research *and* teaching activities. Currently 49 academic staff supervise 29 Postdocs and 101 PhD students, and teach 535 Bachelor and 543 Master students.

The Faculty is led by a Dean, and Departments are led by a Head of Department. The Dean and the three Heads of Department for Electrical Engineering, Mathematics and Computer Science form the Management Team of the Faculty, assisted by a Managing Director and the Financial Controller. Research groups are lead by a Head of Group. The Heads of Group are responsible for research focus, quality of teaching from group members, financial matters, and human resources in the research group. The dean, heads of department and heads of group are normally full professors appointed to an established chair.

**1. Mission statement**

The mission of the Faculty (and thus also of the three departments) as formulated in the "Strategisch Plan Faculteit Elektrotechniek, Wiskunde en Informatica 2006-2009" is:

**"To perform academic teaching and cutting edge, multidisciplinary research in Electrical Engineering, Computer science and Mathematics".**

The faculty has identified four broad research themes to bundle the activities of the 26 different research groups from Electrical Engineering, Mathematics and Computer Science under the flag of "Smart Systems Design". The themes are:

1. Sensors and components
2. Sensor networks
3. Secure information systems and human interaction
4. Dynamic systems and processes

Computer Science contributes to all four themes but the emphasis is on themes 2 and 3.

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<sup>1</sup> VSNU, January 2003

## 2. Leadership and management

The faculties of the University of Twente are primarily responsible for teaching, whereas the institutes of the University are primarily responsible for research. Faculties are divided into departments, which are divided further into research groups. These research groups are also the smallest unit of organisation within the institutes. This creates a matrix structure where research groups are controlled both by the dean of a faculty and the director of an institute. The formal responsibility towards the College van Bestuur (Executive Board) for research activities carried out under responsibility of the Institutes rests with the Scientific Directors. The Directors receive budget from the university using a transparent and detailed model. Much of this budget is based on research output from research groups and is thus unconditionally channeled to these research groups. A 'tax' is levied to fund the infrastructure and to support staff members who are employed by the Faculty but outside the research groups. Scientific Directors are also allocated a Strategic Research Incentive budget which they use to initiate innovative research. All staff are employed by the faculty, and research groupheads are responsible for HRM with regard to teaching and research within their groups.

The table below lists the nine Computer science research groups and the management responsibilities.

	<b>Dean Prof.dr.ir A.J. Mouthaan</b>
<b>Scientific Director prof.dr. P.M.G. Apers</b>	Architecture and Services of Network Applications (ASNA) Vacancy (ad interim Dr. M. J. van Sinderen)
	Computer Architecture Design and Test for Embedded Systems (CAES) Vacancy (ad interim: Dr. G.J.M. Smit)
	Design and Analysis of Communication Systems (DACS) prof.dr.ir. B.R.H.M. Haverkort
	Databases (DB) prof.dr. P.M.G. Apers
	Distributed and Embedded Systems (DIES) prof.dr. P.H. Hartel
	Formal Methods and Tools (FMT) Vacancy (ad interim Dr. A. Rensink)
	Human Media Interaction (HMI) prof.dr.ir. A. Nijholt
	Information Systems (IS) prof.dr. R.J. Wieringa
	Software Engineering (SE) prof.dr. M. Aksit

Fig. 1: The table lists the nine Computer science research groups and the management responsibilities.

The Faculty of Electrical Engineering, Mathematics and Computer Science was established in the summer of 2002, during the year that separates the previous assessment period (1996-2001) from the current interim assessment period (2003-2005). Before 2002, the Faculty of Computer Science was an independent faculty, represented as such in the management structure of the University.



The focus of the faculty into the four areas mentioned in section 1 are the result of a thorough consultation period. The Faculty has been able to make a number of strategic choices to balance its books. After a brief period of stabilisation, new investments will be possible after 2008.

All teaching and research is done in research groups. A head of group is responsible for the scientific direction of the research programs carried out in his/her research groups. A head of group reports on this research to the Scientific Director of the institute under which the specific program resides. Institutes like CTIT have internal and external advisory boards where program choices are discussed. The Scientific Directors are responsible for new research initiatives in fields that might span more than one research group. Funds allocated for this are under his/her control and a scientific director can, in consultation with the Dean and the groups, provide a budget for new (temporary) appointments, investments, and/or existing staff members to engage in new activities. Directors as well as the Dean have the right to propose new professorial positions to the Executive of the University. In all appointment committees of key research staff, the Faculty and the Institute are represented. The Dean is represented on the management board of all relevant institutes. This structure provides a framework where the interests of individual groups, the Department, and the University are balanced, and where strategic decisions can be made.

Within the Department, a monthly meeting takes place between all heads of group, the Dean, and the Head of Department to discuss current affairs affecting the discipline of Computer Science and to advise the management team of the faculty where needed. Every year towards the summer, a management meeting takes place between the management team of the faculty and each individual research group to discuss and report on the situation of the research group with respect to teaching, research, personnel management and finances. A head of group carries formal responsibilities in these areas and in these meetings the head of group is held accountable. These meetings can lead to decisions regarding the future of the research groups on any of these issues.

During the reporting period, one major decision was made as a result of a management meeting with two groups (APS and ARCH), which were merged to form the current ASNA group. The management and the groups involved agreed that this should lead to better focus and critical mass in the general area of Telematics.

A head of group is responsible for motivating the staff. The head of group conducts personnel assessments and job satisfaction meetings and proposes staff development plans when needed. All financial aspects regarding personnel management rest with the Dean. Changes of profile or research orientation take place under the Dean's leadership, in consultation with Scientific Directors. It is Faculty policy to limit group sizes to a manageable size of a maximum of about 30 people since stimulating group processes are likely to happen on that scale. Larger groups tend to fracture and smaller groups can become sub-critical. The general management style is participatory; both within the groups and at the Faculty level, but responsibilities are clearly defined so that decisions can be made effectively and efficiently. The number of committees is kept to the legal minimum, and appointed managerial staff are considered responsible and accountable.

In this framework, where scientific directors can initiate new activities, care must be taken to deal with the opposite side also: redirecting or terminating existing activities. For the most part, this happens automatically: science develops and so do staff members. Occasionally, activities have to be redirected and the management has to direct these changes. Deans and Directors have a shared responsibility here, and the fact that all personnel is appointed in the faculty is merely an administrative arrangement.

National research consultation takes place in a large number of ways: scientific meetings, project meetings, collaborative activities, etc. A formal forum is the "Informatica-kamer" of the VSNU, where Department Heads and/or Deans of all Dutch Universities with a Computer Science department meet and discuss issues of mutual interest.

Quality control is done through a yearly reporting of all scientific research activities in a QAR (Quality Assessment Report). Statistics of publications and about projects/PhD students are kept, and the results of this report are discussed in the yearly management meeting between the management team and individual research groups. The financial allocation system is largely dependent on research output and provides a strong incentive to focus on relevant subjects for which national and international funding schemes have been set up.

### 3. Strategy and policy

#### *Historical context and design in brief*

When the faculty of Computer Science was formed in 1981 an explicit choice was made to focus on applications in a multi-disciplinary setting. This is reflected in our teaching, for example since 1993 we run a successful Bachelor and Master course on Business Information Technology. The focus on applications is also reflected in our research, for example the four research themes mentioned earlier all contribute to the general area of ambient intelligence. A focus on applications in a multidisciplinary setting does not mean that fundamental research is ignored, on the contrary. However, we find much of our research inspiration in the applications. For example we worked on the control algorithms for the flood control barrier built in the late nineteen's near Rotterdam in the Netherlands. The verification work was carried out by the Dutch firm CMG in collaboration with the FMT group. This led to a very successful line of research in model checking which has put Twente at the cutting edge of research today. On December 1st 2006, The University of Twente awarded an honorary doctorate to Dr Gerard Holzmann of NASA/JPL Pasadena, California in recognition of his work on model checking. More recently, a spin off company from the CAES group, Ambient Systems, has started to commercialise our research in Wireless Sensor networking. Many research challenges are emerging from the deployment of WSN in tropical seas, offices, potato fields, etc.

#### *Future development*

In our multi-disciplinary research approach we focus on three aspects of Smart Systems Design: *Interaction, Design* and *Properties*. The nine CS groups form three clusters of three, each focusing on one of these aspects as follows:

- *Interaction focus.* The purpose of all ICT is to support people in their daily life, which means that the success or failure of ICT depends firstly on how well it interacts with people. The HMI group focuses on capturing, analysis, fusion, interpretation, transformation and fission of multi modal data. The DB group focuses on the management of multi modal data and specifically on ways to avoid overloading users with data. The IS group focuses on the interaction of business processes and ICT systems and services.
- *Design focus.* The heart of an ICT system is the software, which is complex, rapidly evolving, and costly to build and maintain. The first concern of designers is to deliver software with the required functionality at acceptable cost. The FMT group focuses on rigour in design and verification, in the context of both software and hybrid systems. The SE group focuses on reusable and composable designs. The ASNA group focuses on context aware service oriented design.
- *Property focus.* An ICT system that satisfies its functional requirements is fit for purpose only if it also satisfies a number of additional properties. The DACS group focuses on dependability properties and performance. The DIES group focuses on security properties and the CAES group focuses on energy efficiency properties.

The multi-disciplinary approach at Twente is successful because it is built on strong disciplines (Electrical Engineering, Computer Science and Mathematics), and the cooperation between the disciplines is effectively supported by the EEMCS faculty as well as the CTIT research institute. In particular, the research of all research groups is embedded within the Strategic Research Orientations (SRO) of CTIT (these are coherent multidisciplinary research programs). The table below lists the SRO's and the participation of research groups in Computer Science.

CTIT SRO's	Participation from CS (*=leading group)		
	<i>Interaction focus</i>	<i>Design focus</i>	<i>Property focus</i>
ASI (A-Services Internet)	IS	ASNA*, SE, FMT	DACS
ISTRICE (Integrated Security and Privacy in a Networked World)	DB, IS	-	DACS, DIES*
UBRICKS (Building Blocks for Ubiquitous Computing and Communication)	-	FMT, SE	CAES*, DACS, DIES
NICE (Natural Interaction in Computer mediated Environments)	DB, HMI*	-	-
eHealth (ICT-in-Healthcare)	IS*, HMI	ASNA	CAES
eProductivity	IS	-	-

Note: an entry marked - indicates that computer science is not involved in this area, while other groups do contribute.

Strategic research in the university Institutes:

#### CTIT

The mission of CTIT is to excel in the design and implementation of advanced Telematics and Information Technology Systems and their integration in user environments. The research program is based on the view that to address the complex issues raised by ICT and its role in society a multidisciplinary approach is needed. To be effective, issues need to be looked at from different and complementary perspectives. Integration of technology-based ICT research and its application in specific domains is a clear focus of CTIT. To that end, CTIT aims at combining a range of disciplines from the technical and social sciences into coherent programs or 'Strategic Research Orientations' (SROs).

The research activities of the former Twente Embedded Systems Initiative (TESI) have been absorbed into the SRO UBRICKS and the TESI teaching activities have been absorbed into the recently approved 3TU master program Embedded Systems.

#### *Co-operation with other technical universities in the Netherlands*

The excellent co-operation with the other two universities of technology has recently been formalized in NIRICT, the Netherlands Institute for Research on ICT. The strategies and policies on research are discussed and compared. New professors are only appointed after discussion by the board of NIRICT. A landscape has thus evolved where groups with sufficient critical mass around focal points based on strategic choices and strengths of existing groups at the three universities are working in complementary fields. The collection of different application areas is so rich that each institute also spans a sufficiently wide area of Computer Science as to support a bachelor programme and several master programmes with specialized tracks. With the increase in cooperation through the 3TU Graduate School and the 3TU Institute of Science and Technology it is expected that the cooperation between the faculties will gain in momentum. In the appendix a copy is added of a 'tuning' document describing the complementary activities at the three institutes.

#### *Embedding within external (national and international) programs*

All scientific staff are (inter)nationally active in conferences, editorial boards, and advisory and steering committees. The most prestigious of these activities are reported in detail in the group reports. The university institutes have a major role in defining the national research agenda NOAG-ICT, and members of the staff are active in the management boards for open programs. Important activities are carried out in national programs, such as BSIK, and Smart Mix. More detailed reports

are in the descriptions of group activities. A significant number of bilateral contacts and collaborations exist with universities outside the Netherlands; these are also detailed in the group reports.

#### 4. Researchers and other personnel

All staff is employed by the faculty. University institutes only employ a scientific director, a managing director, and a minimum of secretarial staff. It is faculty policy that all permanent academic staff contribute to teaching *and* research. This is also true for part time professors, commonly appointed on positions provided for by industry. Full time staff also contribute to the management activities. PhD students and post docs spend most of their time doing research, they may contribute to teaching. The actual tasks of permanent academic staff members are determined by the head of group; and depending on work load and competencies, some staff are more inclined towards research and some toward teaching. These inclinations also change over time. It is faculty policy to encourage people to take study and sabbatical leave to support the dynamics in focus of research. Budget limitations and cuts have minimised the possibilities for expanding the staff size.

Human resource management takes place through annual meetings between a staff member and the head of group. In one type of meeting (jaargesprek), an open discussion takes place on all factors influencing the productivity and well-being of the staff member. Steps can be agreed on by both parties to enhance the cooperation and performance. In such cases the targets are set down in an agreed POP (Persoonlijk Ontwikkelings Plan). The other type of meeting (beoordelingsgesprek) is an assessment of achieved results, normally based on agreed targets from the year before. This assessment is archived in the personnel file.

A head of group is normally a full time professor appointed to an established chair. Recruitment is by rule done internationally. A description of the field of activity is made by the Dean, Head of Department and the Scientific Director(s). These descriptions are kept short and relatively open ended since it is important to attract young, eminent scientists and give them some freedom to develop their field further. Part time professors are appointed if there is a faculty/institutional interest in providing seniority for a specific sub-field for which collaboration with an external partner(s) is fruitful. These appointments are normally financed by third parties and made for a period of 3 years. Personal chairs are awarded to existing permanent staff in sub-fields of substantial breadth and size within research groups. Candidates must be outstanding in their field.

The quality of the academic staff is illustrated by a number of prestigious prizes that have been awarded over the reporting period, or by a number of appointments of former staff at professorial level in institutions of high reputation:

- 2004 Ling Feng was awarded an NWO VIDI grant for the project ContextData: Towards Context-Aware Data Management for Ambient Intelligence.
- 2003 Mariët Theune was awarded an NWO meervoud grant entitled Angelica: A Natural-language Generator for Embodied, Lifelike Conversational Agents.
- 2003 Joost-Pieter Katoen was appointed full professor at RWTH Aachen
- 2004 Holger Hermanns was appointed full professor at Saarbrücken University.
- 2003 Paul Grefen was appointed full professor at the Technische Universiteit Eindhoven
- January 1<sup>st</sup> 2007 Boudewijn Haverkort was elected Fellow of the IEEE "for contributions in performance and dependability evaluation of computer and communication systems".

Table 1

<b>Research staff at institutional level (in full time equivalents)</b>			
Name and present title	2003	2004	2005
<b>Institutional level</b>			
Tenured staff	23,2	22,1	20,5
Non-tenured staff	14,3	15,0	28,7
PhD-students	55,0	56,7	73,8
Total staff	92,5	93,8	122,9

*Supporting staff*

Technical and administrative support is organized at various levels. Each research group has one or more secretaries and some technical staff to support research and teaching. ICT support exists at the faculty level (network management) and also at the University level (network, infrastructure). It is impossible to break this down to a price per research group. The same holds true for support from the financial department. The faculty has a personnel department, but many processes take place at the university level. As a whole the UT spends 55-60% of its direct government budget (first budget stream) on overhead (30-35% at central level and 25% at faculty level). The ratio of the academic staff (inc. postdocs and PhD's) to non-academic staff in the faculty (including Electrical Engineering and Mathematics) is 460:160 (ac:non-ac) or 2.9:1. At University level this ratio is 1.4:1.

**5. Resources, funding and facilities**

The financial system has changed over the reporting period. Since the year 2002, a system without fixed allocations is in use; all research group income is determined by the research and teaching output measured over preceding years, as follows. For teaching, the volume (number of students with passing marks times the number of ECTS) is the sole parameter. For research, there are a number of parameters, as will be explained below. Before 2002, a system with fixed funding of agreed targets was used. Both systems will be explained here briefly, and their consequences for budget allocations and strategic choices for spending will be discussed.

Before 2002 research was financed on the basis of preset targets for permanent staff (fixed base financing) with an additional variable component (approx. 30%), depending on the number of publications by the group according to a point system. For the last 10-15 years, this way of funding has led to a situation where the budget from the university (1st budget tier) was mainly used to invest in permanent staff capacity, since this staff is the primary source of generating projects, and, therefore generating income from the 2<sup>nd</sup> and 3<sup>rd</sup> budget tiers, which eventually leads to more publications. The policy of the Faculty has been to allow the appointment of permanent staff when the projections for income in the 1st budget tier of a group permitted such. The Faculty has thus maximized its income generating capacity. The disadvantage of this policy is that, when budget cuts are faced, financial problems arise at the group level. In general, it is difficult to finance permanent staff on projects from 2<sup>nd</sup> or 3<sup>rd</sup> budgets sources.

Starting 2002, the University introduced a financial system for the 1st budget tier that funds groups entirely on the basis of their volume of output in teaching and research. Figure 2 shows the structure. First, university overhead is deducted, then a 1/3 – 2/3 division is made for teaching and research respectively. The available research funds are split: one part is distributed to research groups on the basis of their teaching activities (so called unrestricted teaching-related research funding, meant to keep abreast with developments through personal research), one part is set aside for targeted research initiatives (at the central and institute levels), and the remaining part is distributed depending on the number of PhD students present in the group. A group is directly financially rewarded by the Ministry of Education with a fixed amount per graduating PhD student. At the research group level, all these sources of income are added, and constitute the budget for

the 1st money tier. A group is asked to make an integral budget estimate for a calendar year where income from 1<sup>st</sup> (University funding), 2<sup>nd</sup> (research council funding) and 3<sup>rd</sup> (Industry and European funding) money tiers is integrated. Each group is taxed to finance the Faculty overhead (management, student administration, personnel support, financial group) and the services enjoyed by the group (office/lab space, ICT support). These integrated budgets need the approval of the management team. Heads of group are expected to manage the distribution of tasks and budgets within their group. A group generally has financial reserves as a result of income generated and expenditure made. These funds remain allocated to the groups, but withdrawal needs the approval of the management team because the collective reserves form the reserve position of the university as a whole, and are, therefore, subject to financial (solvability) contracts with banks. Individual staff members have no personal budgets, but their activities contribute to group funds; Heads of group recognize and stimulate successful activities of individual group members. During the yearly management meeting of the group with the management team, the financial position of the group is discussed (after a discussion on research and teaching). The root cause of financial difficulties is generally the profile in research (research is the only really variable income parameter), and ways are sought to improve this capacity.

Above group level strategic discussions takes place in the boards of institutes and at the Faculty level at times when a strategic plan has to be written. The most recent strategic plan dates from 2006. It was written to cope with budget cuts, reduced intake of undergraduates, and a further sharpening of the profile. The discussions on 3TU federation will further stimulate these discussions.

The university financial system sets aside 20% (10% at central level and 10% at institute level) of its 1<sup>st</sup> budget tier for innovation. This is a substantial amount of money allocated to strategic programs (SRO's in the institutes, but also programs at the inter-institute level). Decisions made on the programs at the institutional level are under the directors' responsibility and at the university level under the responsibility of the executive board. These programs take 3-5 years to execute and thus generate an innovation in profile and direction of 10-20% per 3-5 years. This innovation is normally carried out by existing permanent staff.

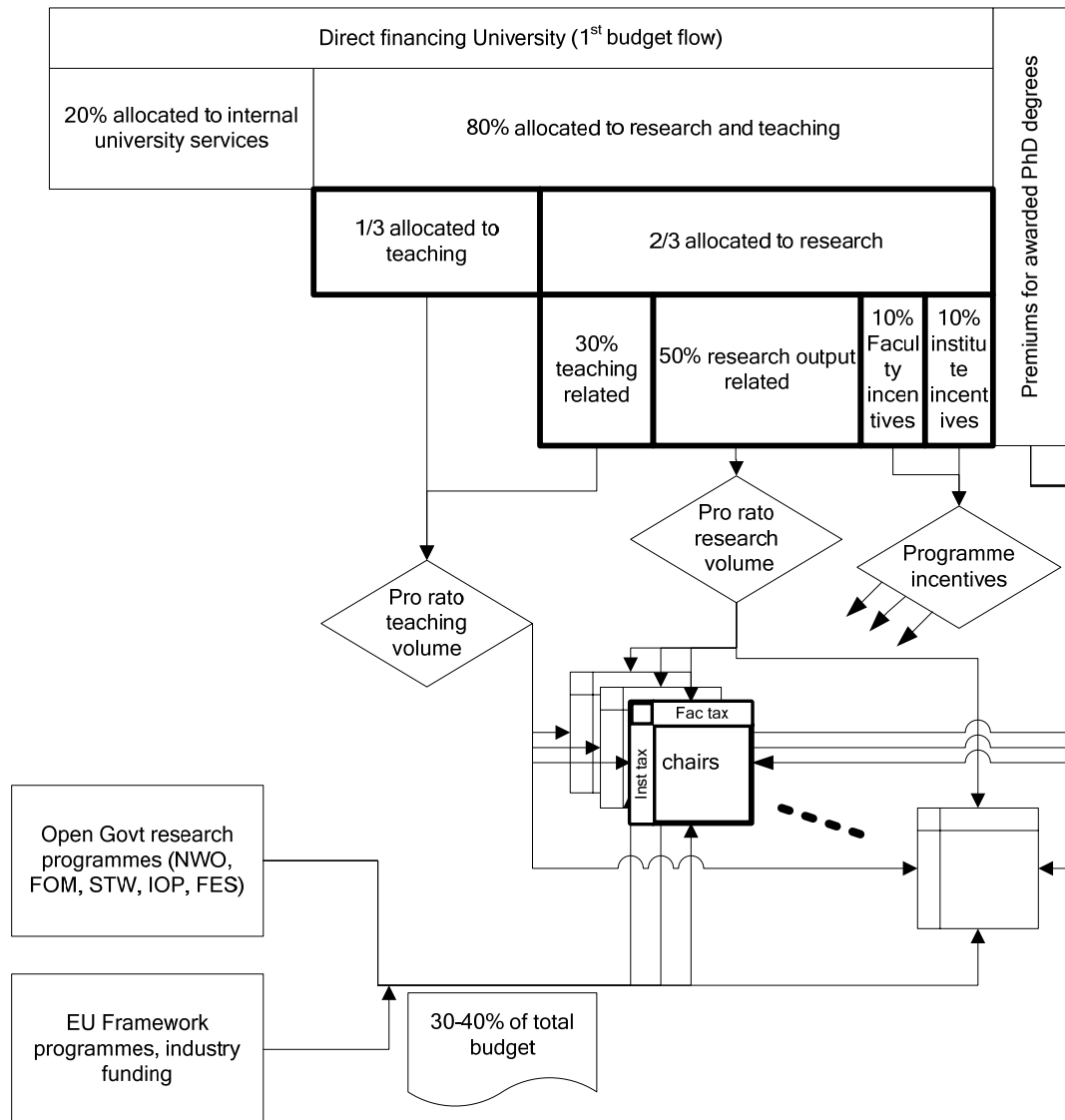


Fig. 2 Funding system.

Most research groups have lab facilities, there are well advanced plans to create a “living lab” in the computer science building that will link the labs of the individual groups, both within the University and with the Universities of Delft and Eindhoven. The library facilities are being centralized at the university. In the budget year 2005 and the following years, a structural deficit has arisen of approx. 10% in funding at group level due to various reasons. A discussion with Directors of the Scientific Institutes will take place on prioritizing research themes and redirecting funding.

In table 2 the yearly funding according to the budget is indicated.

*Table 2*

<b>Funding and expenditure at institutional level (in K€)</b>			
<b>Institutional level:</b>			
<b>Funding:</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>
Direct funding (1 <sup>st</sup> )	10.048	10.228	10.384
Research funds (2 <sup>nd</sup> )	1.079	1.162	1.450
Contracts (3 <sup>rd</sup> )	2.775	2.808	3.826
Other			
<b>Total</b>	<b>13.902</b>	<b>14.198</b>	<b>15.660</b>
<b>Expenditure:</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>
Personnel costs	8.122	8.587	10.727
Other costs*	5.032	5.838	5.586
<b>Total</b>	<b>13.155</b>	<b>14.425</b>	<b>16.313</b>

\* other costs include housing (2003: K€ 430; 2004: K€ 875; 2005: K€ 917)

## 6. Overview of the results

A full overview of scientific output is given in table 3. Only international, reviewed publications in publicly accessible sources are shown. There will be a significant increase in PhD's and consequently in the number of publications in the coming years. There is growing dissatisfaction that the need for research volume can not always be paralleled by an increase of scientific quality. More than 50% of the temporary staff is non-Dutch often requiring even more time for supervision than local students. A similar dissatisfaction is growing by the fact that the research agenda is increasingly determined by outside agencies, often based on relatively short-term issues. Sound academic research is sometimes competing with research with high-level short term applicability.

*Table 3*

<b>Aggregated results of the institute</b>					
		<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>Total</b>
Academic publications	a. PhD-theses	16	12	14	42
	b. in refereed journals	35	43	54	132
	c. international conference proceedings	167	200	298	665
	d. books	2		1	3
	e. book chapters	11	15	21	47
<b>Total</b>		<b>231</b>	<b>270</b>	<b>388</b>	<b>889</b>
International patents		2	1	1	4



## 7. Analysis, perspectives, and expectations for the institute

A series of major decisions has been instrumental in the development of research in the department over the reporting period:

1. The choice at the university level for focal institutes with extra incentives for research activities. The discipline of Computer Science is affected only by the creation of CTIT. The institute has focussed ongoing research activities, has created more critical mass, attracted challenging projects, has been helpful in defining national agendas for research, has stimulated cooperation, and helped to establish a complementary distribution of research subjects and strongholds in The Netherlands.
2. The financing system for permanent staff, basic infrastructure, and building has been wholly made dependent on research and teaching output. This has stimulated an outward view and a proliferation of research contacts and contracts.
3. The merging of 3 faculties (Electrical Engineering, Computer Science and Applied mathematics) has intensified contacts and collaboration and created enhanced efficiency in support services.

### *Strengths*

1. The CTIT SROs have proven to be successful areas in sustaining a substantial research volume in relevant areas, and the SRO's have stimulated cooperation and integration of competencies.
2. There is an excellent atmosphere conducive to research with motivated, highly productive staff.
3. Notwithstanding budget limitations several young key persons have been appointed.
4. Excellence is achieved in some areas. Research in all areas is more than adequate to fulfil the societal need in educating top level graduates.
5. There is an innovative atmosphere, where spin-off companies are stimulated and established companies are eager to recruit our graduates.
6. 2<sup>nd</sup> and 3<sup>rd</sup> budget tier research volume has increased and is stimulated through strong output financing.
7. One faculty in which Electrical Engineering, Mathematics and Computer Science are integrated brings coherence, cooperation and critical mass.

### *Weaknesses*

1. A strong focus on external projects in some areas might shift research to short term issues in lieu of fundamental research.
2. Program orientation of all research themes results in (inter)national research agendas determining local research policy; we are no longer in the driving seat for some areas.
3. It takes too many PhD students longer than four years to complete their thesis.

### *Opportunities*

1. The university hopes to be able to introduce a tenure track system.
2. Program development within Institutes secures critical mass, embedding, and greater possibility for influencing (inter)national research agendas.
3. 3TU- cooperation creating national research agendas increases the 3TU participation in industrial innovation in The Netherlands in general, and in NIRICT and CeDICT in particular.
4. 20% of the research budget reserved for Strategic Research Orientations makes it possible to relocate a substantial amount of resources in a relatively short period of time.
5. We are in the position to determine the national research agenda in a number of areas, such as embedded systems and security & dependability.

### *Threats*

1. It is proving difficult to find highly qualified staff at all levels, ranging from PhD's to professors.

2. Budget cuts (or budgets not keeping up with rising costs) undermine development, innovation, and ultimately morale.
3. Full output based financing creates an accountability problem and a mindset of reporting/calculating/administrating instead of attention to the primary processes.
4. There is an almost impossible problem in matching externally funded research contracts.
5. The undergraduate intake is shrinking.

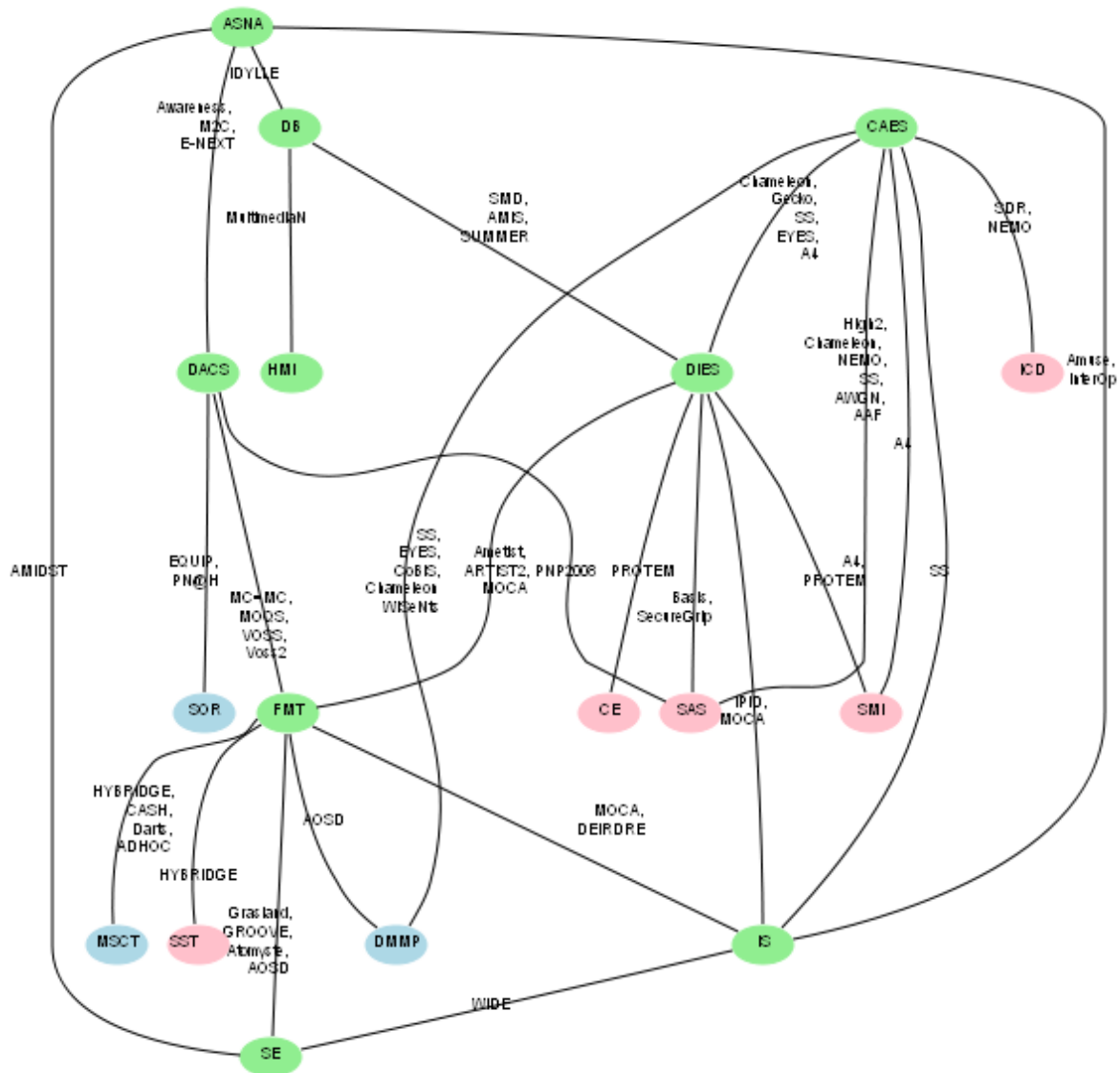


Fig. 3 The diagram shows how the nine computer science groups (shown in green) cooperate both with each other and with many of the electrical engineering (pink) and mathematics groups (blue) of the faculty, in 47 different externally funded research projects. Co operations with groups outside the faculty and the university are not shown.

**Section B: Documentation of the research program**



**Part I Interaction Cluster**

The purpose of all ICT is to support people in their daily life, which means that the success or failure of ICT depends first of all on how well it interacts with people. We present the research of the Computer Science groups that focus on Interaction:

1. The HMI group focuses on capturing, analysis, fusion, interpretation, transformation and fission of multi modal data.
2. The DB group focuses on the management of multi modal data and specifically on ways to avoid overloading users with data.
3. The IS group focuses on the interaction of business processes and ICT systems and services.



**Title of the chair's program:**

Databases (DB)

**Subprograms or themes:** none**NABS code:** N07**Chairman:** prof.dr. P.M.G. Apers**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal cooperations:** none**1. Mission statement**

There is a drastic change for ownership of data. Before most of the data was owned by companies and stored in corporate databases, now more and more data is owned by individuals. A growing portion of the data is no longer stored in traditional databases. It is stored as semi-structured data (for example, XML) or even unstructured data. Also there is more variety as far as the creation of data is concerned than before. Think of sensor networks. Also security and privacy issues are becoming more important. A consequence of this all is that formulating and processing of queries is changing. Our mission is:

**'To obtain better insight in data management to deal with information overload'.**

**2. Leadership**

The senior staff of the group consists of Peter Apers, Wim Jonker, and Ling Feng. Peter Apers, as full professor, has final responsibility for research and teaching activities and strategy. Wim Jonker, as part-time professor from Philips, is responsible for security-related activities in the group and provides an intensive cooperation with the largest ICT R&D lab (Philips Research) in the Netherlands. Together with Ling Feng and the assistant professors Maarten Fokkinga, Maurice van Keulen, and Djoerd Hiemstra supervision of the PhD-students is done.

The permanent staff meets every two weeks to discuss in an open way chair-related matters. New research challenges and opportunities are discussed in terms of new collaborations with other research groups or with industry. The staff is motivated to get external funding for our new projects. On the one hand, to enlarge the research volume of the group, and on the other hand, to get continuous feedback from peers on our new ideas (quality control).

Internal communication is done via one-to-one meetings, group meetings, email and wiki discussions, and social events. External communication is done via publications, presentations, demos of prototypes, and our website.

**3. Strategy and policy*****3.a. Design in brief***

Traditionally the group was very strong in query processing in distributed and parallel environments and in developing schema languages for new modelling paradigms (for example, object-oriented data models). Gradually there has been a shift towards retrieval of semi-structured data and multimedia and information retrieval. Recently, security of data and data management for sensor networks were added.

Currently, the group distinguishes four lines of research:

- Querying and IR of XML documents
- Data management in ambient intelligent peer-to-peer environments
- Context-awareness
- Security and Privacy

Orthogonal to this we look at more theoretical issues.

Gradually there has been a shift from research on corporate databases to research on data management for human-centric, retrieval-oriented applications. Important characteristics are: retrieval of semi-structured data or even unstructured data, simpler way of formulating queries (for example, keywords search), usage of context of user to make queries more precise, easier data integration, and security and privacy.

The challenges we address are:

1. How can context and user preferences be taken into account in answering queries to better satisfy a user's information need.
  - a. How can a system acquire automatically the context and preferences of users?
  - b. How can a system guarantee privacy of the automatically acquired context and preferences of users.
2. How to meet the data management demands of ambient intelligent multimedia applications
  - a. How to advance multimedia information retrieval technology to support ambient intelligent applications.
  - b. How to simplify ad hoc data exchange and integration in peer-to-peer environments
3. How to build a full-fledged XML DBMS based on relational database technology
  - a. Find efficient and scalable implementation of the standards that are being proposed
  - b. How to extend XML technology with multimedia information retrieval functionality
4. How to deal with security and privacy issues in multimedia retrieval and e-health where standard access control mechanisms do not suffice.
  - a. How to secure data when the DBMS and its administrator cannot be trusted
  - b. How to balance privacy protection and emergency access requirements in health care data

The research of the group is part of CTIT. The goal of CTIT is to increase the quality of the research and to increase the research volume by acquiring externally funded projects. CTIT has 6 Strategic Research Orientations. The group participates in two of them: NICE and Istrice. Most of the projects in which the group participates are collaborations with other national groups from different sub disciplines of computer science.

### ***3.b. Programme development***

For Information Retrieval we focus on IR on XML documents, with the inclusion of social tagging of multimedia. For data management we work on the integration of peer-to-peer environments taking uncertainty of the data into account and on making systems more proactive by including context information. In more and more applications privacy and security are becoming an issue, e.g. sensor networks and healthcare.

## **4. Processes in research, internal and external collaboration**

Given the focus of the group, external funding for specific projects is acquired to implement our goals. Some projects are submitted by individuals, others are submitted by a consortium of researchers or a mix of researchers and people from industry. In all cases the PhD-students have to work in teams.

The permanent staff meets every two weeks to discuss chair-related issues, such as progress of projects and PhD-students. The whole group meets every month to listen to presentations of PhD-students. In the meantime the daily advisors and PhD students meet frequently; many discussions



take place via the internet (email or wiki's) or in brainstorm sessions. We also have regular meetings with our Master students working on their thesis. We also provide ad hoc presentation sessions for staff members and PhD students before giving a presentation at a conference or for an interview for a grant.

Every year the permanent staff plus the postdocs of the group meet to discuss the future of the group in terms of research and teaching focus. Also, opportunities for new projects are discussed. To improve advising PhD-students, related experiences are exchanged. Furthermore, a yearly team building event is organized for the whole group.

The DB group has over the years been successful in acquiring externally funded projects (NWO, Bsik), resulting in highly visible research results (high quality conferences and journals). Within the faculty there is cooperation with HMI and DIES, and a growing cooperation with CAES (especially sensor networks). In CTIT the group participates in the SRO NICE. Nationally there is a long lasting, strong cooperation with the database group at CWI. At the international level there is contact with quite a few universities and academic institutes. With a couple we have more formal contacts: University of Munich, University of Konstanz, INRIA, and Stanford University.

#### **5. Academic reputation (we mention highlights only, omitting PC membership etc)**

*prof dr. Peter M.G. Apers*

- Scientific director of CTIT
- Chairman of the board of the Technology foundation STW
- Member of advisory board of ICTRegie
- Member of the Endowment of the VLDB (publication chair)
- Member of the steering committee of the EDBT
- Editor of Distributed and Parallel Databases, Kluwer
- Editor of Data and Knowledge Engineering, Elsevier

*prof.dr. W. Jonker*

- Vice president Philips Research
- Sector-head digital lifestyle technology, Philips Research
- Chairman Sentinels
- Co-founder NVSO (Nationaal Samenwerkingsverband Security-Onderzoek)
- Organizer Secure Database Management, VLDB workshops 2004, 2005

*dr. Ling Feng*

- NWO VIDI Vernieuwingsimpuls prize, awarded by the Dutch Organization of Scientific Research (NWO).
- Distinguished International Research Fellow at Curtin University's Centre for Extended Enterprises and Business Intelligence, Australia.
- Distinguished Visiting Fellow of Dept. of Computer Science at Latrobe University, Australia.
- Secretary of the IFIP WG 2.12 on Web Semantics.
- Associate editor of International Journal of Data Warehousing and Mining.
- Guest co-editor of International Journal of Computer Science, System & Engineering on "Trends in XML Technology for the Global Information Infrastructure". Vol.18, No.5, September 2003

*Dr.ir. D. Hiemstra*

- Co-organiser of the Dutch-Belgian Information Retrieval Workshop, DIR 2004, 2005

*Dr.ir. M van Keulen*

- Co-organizer Dutch-Belgian DataBase Day (DBDBD) 2005
- Co-organizer AmbientDB workshop 2003, 2004, 2005
- Co-organizer of EDBT Summerschool 2004
- Member of EDBT association

## 6. External validation

### 6.a. Societal relevance

Information overload is becoming a serious societal problem. More and more data becomes available on the web, making it more difficult to find relevant information. Search engines like Google are still doing a good job, however, keyword search is a rather limited way of formulating queries.

Also the fact that almost all data can somehow be accessed by unauthorized persons is a security threat. Protecting data, not only commercial data, is becoming more and more important.

### 6.b. Industrial contacts

- National: Philips, WCC, TNO, eMaxx, FINAN, Daimler/Chrysler, Proctia, X-Hive, V2, Telematica Instituut, Topicus, Quintica, ICTU, Bizzdesign, Alientrick, Asset Control, Astron, Axis Media-ontwerpers BV, Belastingdienst, DynamicZones, FourPlus, Giarte Media Group BV, Gladior, IAMS, IDgis BV, Indialoog Multimedia, International Instituut for Geo-Information Science & Earth Observatory (ITC), Nederlandse Aardolie Maatschappij (NAM), Nederlands Forensisch Instituut (NFI), Oce, Open Fortress, Ordina, Philips Natlab, PinkRocade, Price Waterhouse Coopers, Prodist, Rabobank, Smurfit Lona Golfkarton, Soliditree, Syntens, Thales, Thinkwise
- International: Microsoft, Business School Netherl. South Africa, IBM Center for Advanced Studies, Oracle, Siemens VDO Trading BV

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Apers, Prof.dr. P.M.G.	0,16	0,16	0,16
associate professor (uhd)	Blanken, Dr. H.M.	0,27	0,16	
	Feng, L.	0,4	0,4	0,4
assistant professor (ud)	Fokkinga, Dr. M.M.	0,4	0,4	0,4
	Hiemstra, Dr.ir. D.	0,4	0,4	0,4
	Keulen, Dr.ir. M. van	0,34	0,4	0,4
<b>Total tenured staff</b>		<b>1,97</b>	<b>1,92</b>	<b>1,76</b>
professor (hgl)	Jonker, Prof.dr. W.	0,09	0,09	0,09
associate professor (uhd)	Blanken, Dr. H.M.			0,06
assistant professor (ud)	Choenni, Dr.ir. R.S.	0,08		0,09
postdoctoral fellows	Anciaux, dr. N.L.G.			0,84
	Blok, Dr.ir. H.E.	1,0	1,0	1,0
junior staff (aio, oio, moz-p)	Boldareva, L.	0,8	0,8	0,23
	Bunningen, A.H. van		0,6	0,8
	Derks, Ir. W.L.A.	0,8	0,8	0,39
	Evers, ir. S.			0,67
	Keijzer, A. de	0,49	0,77	0,8
	Klinger, S.			0,47
	Meratnia, N.	0,8	0,8	0,13
	Mihajlovic, V.	1,0	1,0	1,0
	Petkovic, dr. M.	0,17		
	Rode, H.		0,6	0,8
	Ruth, Drs. J. van	0,8	0,8	0,8
	Serdyukov, P.			0,58
	Smiljanic, M.	1,0	1,0	1,0
other junior staff (moz, twaio)	Zych, A.		0,13	0,8
	Vonk, Ir. J.	0,33		
<b>Total non-tenured staff</b>		<b>7,36</b>	<b>8,39</b>	<b>10,55</b>
<b>Total Research staff DB</b>		<b>9,32</b>	<b>10,31</b>	<b>12,31</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

Besides work place PCs/Laptops (Linux and Windows), we have a lab room with a varying number of on average 10 PCs (Linux and Windows) and a SUN cluster (on average 2 to 4 systems). Especially for our information retrieval research, we had a Linux cluster of 4 High-End Pentium PCs with 200GB of very fast external storage. The cluster was in 2004 replaced by a 64bit Dual-Opteron 1.9GHz with 8GB high-end internal memory and 400GB of fast disk storage.

### 8.b. FTE-funding PhDs/postdocs

Table 5

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	57%	45%	30%	44%
Research funds	29%	24%	44%	32%
Contracts	14%	31%	26%	24%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

<i>Name project</i>	<i>Start date</i>	<i>End date</i>	<i>Sponsor</i>
AMIS: Advanced Multimedia Indexing and Searching	1-7-1997	1-5-2003	NWO
CIRQUID: Complex Information Retrieval Queries in a DBMS	16-10-2002	1-12-2006	NWO
OPAQUE: Optimization of Pathfinder Queries	1-6-2005	1-7-2010	NWO
CADMAI: Towards Context-Aware Data Management for Ambient Intelligence	1-3-2005	1-3-2010	NWO-VIDI
Philips-PRISMA: A distributed main-memory database machine	1-2-2003	1-2-2007	Philips Electronics
Secure Meta Data: Secure Content Management In Ambient Environments	1-2-2003	1-2-2007	Philips Electronics
BRICKS/PDC1: Security, Identification and Authentication	1-1-2004	1-1-2009	SENER / BSIK
MultimediaN/N3: Multimedia databases	1-1-2004	1-1-2009	SENER / BSIK
MultimediaN/N5: Semantic access	1-1-2004	1-1-2009	SENER / BSIK
GRAAL: Guidelines Regarding Architecture ALignment	1-9-2002	31-12-2005	Telematica Instituut

## 9. Overview of the results

### 9.a. Description of scientific results

The recent results that we are most proud of are:

- Significant advances on information retrieval for XML and multimedia retrieval
- Construction of one of the fastest XML database management systems based on relational technology
- Laying the foundations for the novel and quickly rising topic of context awareness
- Significant advances on secure data management, in particular searching in encrypted data
- Significant advances on schema and data integration, in particular clustering techniques for schema matching and probabilistic database techniques for data exchange and integration.

**9.b. Key publications**

Table 7

nr	Title
1	<i>L. Feng, T. Dillon, Using Linguistic representations to Provide Explanatory Semantics for Data Warehouses, IEEE Transactions on Knowledge and Data Engineering, 2003, vol. 15, no. 1, pp. 86-102</i>
2	<i>T. Grust, M. van Keulen, J. Teubner, Staircase Join: Teach a Relational DBMS to Watch its (Axis) Steps, In: J.-C. Freytag, P.C. Lockemann, S. Abiteboul, M. Carey, P. Selinger, A. Heuer / Proceedings of the 29th International Conference on Very Large Databases, VLDB'2003, Berlin, Germany / September 2003 / Morgan Kaufmann Publishers / ISBN 0-12-722442-4, pp. 524-535</i>
3	<i>H. Zaragoza, D. Hiemstra, M. Tipping, S.E. Robertson, Bayesian Extension to the Language Model for Ad Hoc Information Retrieval, In: Proceedings of the 26th Annual International ACM Conference on Research and Development in Information Retrieval (SIGIR '03) / 2003, pp. 4-9, ISBN: 1-58113-646-3</i>
4	<i>T. Grust, M. van Keulen, J. Teubner, Accelerating XPath Evaluation in Any RDBMS, Transactions on Database Systems (TODS), March 2004, vol. 29, no. 1, pp. 91-131, ACM Press, New York, NY, USA, ISSN 0362-5915</i>
5	<i>M. van Keulen, A. de Keijzer, W. Alink, A probabilistic XML approach to data integration, In: Proceedings of the International Conference on Data Engineering (ICDE), 5-8 April 2005, Tokyo Japan / April 2005 / IEEE Computer Society / ISBN 0-7695-2285-8, pp. 459-470</i>

**9.c. Numerical overview of the results in a fixed format of categories**

Table 8

		2003	2004	2005
1 Academic publications	a. PhD-theses	2	1	2
	b. in refereed journals	7	7	7
	c. international conference proceedings	24	16	31
	d. books	1		
	e. book -chapters	6		4
<b>Total</b>		40	24	44
2. International patents			1	

**9.d. Full outcome list****2003***PhD-theses*

Campos dos Santos, J.L. A Biodiversity Information System in an Open Data/Metadatabase Architecture. (2003, juni 4). 254 pp. Enschede ITC Thesis advisor(s): Prof.dr. P.M.G.

Apers, Dr.ir. R.A. de By. ISBN: 90-6164-214-0

Petkovic, M. Content-Based Video Retrieval Supported by Database Technology. (2003, februari 28). 171 pp. Enschede Universiteit Twente Thesis advisor(s): Prof.dr. W. Jonker. ISBN: 90-365-1866-0

*Journal articles*

Choenni, R.S. , Bakker, R., Baets, W. On the Evaluation of Workflow Systems in Business Processes. Electronic journal of information systems evaluation nr: 2, 6, (2003). (pp. 33-44) ISSN: 1566-6379

- Feng, L. , Dillon, T. Using Linguistic Representations to Provide Explanatory Semantics for Data Warehouses. IEEE transactions on knowledge and data engineering nr: 1, 15, (2003). (pp. 86-102) ISSN: 1041-4347
- Feng, L. , Dillon, T., Chang, E. Schemata Transformation of Object-Oriented Conceptual Models to XML. International journal of computer systems science and engineering nr: 1, 18, (2003). (pp. 45-60) ISSN: 0267-6192
- Jonker, W. XML and secure data management in an ambient world. SPECIAL ISSUE: Trends in XML Technology for the Global Information Infrastructure International journal of computer systems science and engineering nr: 5, 18, (2003). (pp. 311-317) ISSN: 0267-6192
- Lu, Hongjun , Yu, J.X., Feng, L., Li, Z. Handling Data Skew in Parallel Data Cube Computation. Distributed and parallel databases nr: 2, 13, (2003). (pp. 181-202) ISSN: 0926-8782
- Tung, A.K.H. , Lu, Hongjun, Han, J., Feng, L. Efficient Discovery of Inter-Transaction Association Rules. IEEE transactions on knowledge and data engineering nr: 1, 15, (2003). (pp. 43-56) ISSN: 1041-4347
- Westerveld, T.H.W. , Vries, A.J. de, Ballegooij, A. van, Jong, F.M.G. de, Hiemstra, D. A Probabilistic Multimedia Retrieval Model and its Evaluation. Eurasip journal on applied signal processing 2, (2003). (pp. 186-198) ISSN: 1110-8657

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- Boldareva, L. , Hiemstra, D., Jonker, W. Relevance feedback in probabilistic multimedia retrieval. DELOS Workshop on Multimedia Contents in Digital Libraries Crete, Greece
- Choenni, R.S. , Bakker, R., Baets, W. Impact of workflow systems on business processes. Proceedings 10th European Conference on IT Evaluation (2003). (pp. 113-123) Madrid, Spain MCIL Press ISBN: 0-9544577-3-0
- Chong, C.N. , Corin, R.J., Etalle, S., Hartel, P.H., Jonker, W. LicenseScript: A Novel Digital Rights Language and its Semantics. 3rd Int. Conf. on Web Delivering of Music (2003). (pp. 122-129) Leeds, United Kingdom IEEE Computer Society Press, Los Alamitos, California ISBN: 0-7695-1935-0
- Feng, L. Supporting Intelligent Querying Over Multimedia Digital Libraries. Proceedings of the 3rd International Conference on Intelligent Multimedia Computing and Networking (2003). (pp. 1295-1298) North Carolina, U.S.A. ISBN: 0-9707890-2-5
- Feng, L. , Dillon, T., Weigand, H., Chang, E. An XML-Enabled Association Rule Framework. Database and Expert Systems Applications Lecture notes in computer science nr: 2736, 2736, (2003, september 1 / 2003, september 5). (pp. 88-97) Heidelberg Springer verlag ISBN: 3-540-40806-1 / ISSN: 0302-9743
- Feng, L. , Jonker, W. Efficient Processing of Secured XML Metadata. On The Move to Meaningful Internet Systems 2003: OTM 2003 Workshops Lecture notes in computer science nr: 2889, 2889, (2003, november 3 / 2003, november 7). (pp. 704-717) Heidelberg Springer Berlin ISBN: 9783540-20494-7 / ISSN: 0302-9743
- Grust, T. , Keulen, M. van, Teubner, J. Staircase Join: Teach a Relational DBMS to Watch its (Axis) Steps. Proceedings of the 29th International Conference on Very Large Databases (2003). (pp. 524-535) Berlin, Germany Morgan Kaufmann Publishers ISBN: 0-12-722442-4
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- Meratnia, N. , By, R.A. de A New Perspective on Trajectory Compression Techniques. Proceedings of ISPRS Commission II and IV. Working Groups II/5, IV/1 and IV/2 Joint Workshop on Spatial, Temporal and Multidimensional Data Modelling and Analysis (2003). 8 pp. Quebec City, Canada
- Meratnia, N. , By, R.A. de Trajectory Registration and Compression for Regular Traffic. Proceedings of the 5th Geomatic Week "Cartography, Telematics and Navigation" (2003). 10 pp. Barcelona, Spain
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- Rajagopal, R. , Chang, E., Dillon, T., Feng, L. XML View. Proceedings of the 14th International Conference on Data and Expert Systems Applications (DEXA'03) (2003). (pp. 148-159) Prague, Czech Republic ISBN: 3-540-40806-1
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- Teubner, J. , Grust, T., Keulen, M. van Bridging the GAP Between Relational and Native XML Storage with Staircase Join. Tagungsband zum 15. GI-Workshop Grundlagen von Datenbanken (2003). (pp. 85-89) Tangermünde, Sachsen-Anhalt, Germany Universität Magdeburg
- Westerveld, T.H.W. , Ianeva, T., Boldareva, L., Vries, A.P. de, Hiemstra, D. Combining Information Sources for Video Retrieval. Proceedings of the 12th Text Retrieval Conference (TREC-12) (2003). Gaithersburg, U.S.A.
- Wieringa, R.J. , Blanken, H.M., Fokkinga, M.M., Grefen, P.W.P.J. Aligning application architecture to the business context. Conference on Advanced Information System Engineering (CAISE 03) (2003, juni 16 / 2003, juni 20). (pp. 209-225) Heidelberg Springer-Verlag
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#### *Books - author*

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- Grust, T. , Keulen, M. van Tree Awareness for Relational DBMS Kernels: Staircase Join. Intelligent Search on XML Data Lecture notes in computer science Lecture Notes in Computer Science nr: 2818, (2003). (pp. 231-245) Heidelberg Springer Berlin ISBN: 3-540-40768-5 / ISSN: 0302-9743

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### **10. SWOT-analysis (excluding SWOT items already mentioned in part A)**

#### *Strengths*

- Ability to attract external funding
- Good level of funding from NWO

#### *Weaknesses*

- To scientifically capitalize on our research results
- Added-value of many collaborations is insufficient

#### *Opportunities*

- Multimedia and internet applications are hot topics
- More research funding becomes available for human-centric research

#### *Threats*

- Funding for database research is diminishing



**Title of the chair's research program:**

Human Media Interaction (HMI)

**Subprogrammes or themes:** none**NABS code:** N07**Chairman:** Prof.dr.ir. A. Nijholt & Prof.dr. F.M.G. de Jong**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal co-operations:** TNO-ICT**1. Mission statement**

Human Media Interaction is a broad research field dealing with capturing, analysis, fusion, interpretation, transformation and fission of multimodal data. Syntactic, semantic and pragmatic analysis of multimodal input and multimedia data can take place in a static (off-line) or dynamic (online) context. In the former case the emphasis is on providing intelligent access (retrieval) to stored multimedia, where 'intelligent' refers to the possibility to manipulate stored multimedia in order to provide cross-modal multimedia presentations. In the latter case we have multimodal interaction with reactive and pro-active smart environments and devices. Mixed reality and virtual humans are among the related research topics that are addressed. In this context, our mission is:

**'To support (multimodal) interactions with and within smart environments and to support the use of and the interaction with multimedia information.'**

**2. Leadership**

The group is managed by the senior research active staff (Nijholt, de Jong) with frequent formal and informal consultation of other staff. In order to help managing the many externally funded projects HMI has appointed a part-time project manager.

In the past the group has made some changes in its research orientations. Presently it is a large and internationally recognized HCI and Multimedia research group with a reputation of original and advanced research. As such there are many invitations to join in establishing European and Dutch research projects, Networks of Excellence and COST actions. These invitations extend to invited talks and lectures at SummerSchools. The group aims at doing research in a multidisciplinary context and is in particular interested to cross existing borders of traditional research areas and research communities. The group has also established a Masters programme Human Media Interaction that allows HMI researchers to teach their research topics and approaches to students. HMI is in the core of the CTIT SRO NICE (Natural Interaction in Computer-mediated Environments). HMI is actively looking for possibilities to create new positions for female researchers and to fill (Ph.D) vacancies with female researchers.

**3. Strategy and policy*****3.a. Design in brief***

HMI research is part of the CTIT Strategic Research Orientation (SRO) NICE (Natural Interaction in Computer-mediated Environments). This SRO provides the context for project acquisition and research.

As stated in the FP7 programme, an important goal for ICT research is "to bring technology closer to people". This can mean hiding the complexity of the technology, revealing the functionality only when it is assumed to be needed and making technology easy to use, available at all time, affordable and adaptable to the users' context and preferences.

All of these are means to improve the ways in which people can interact with technology. The research covered by the Strategic Research Orientation NICE aims to improve the ease of use of new technologies in computer-mediated environments in order to turn smart surroundings into habitable environments.

Closely related is the Ambient Intelligence vision as defined in the statement of the theme of the 2nd European symposium on ambient intelligence (Eindhoven, 2004): "Ambient Intelligence represents a vision of the future where we shall be surrounded by electronic environments, sensitive and responsive to people. Ambient intelligence technologies are expected to combine concepts of ubiquitous computing and intelligent systems putting humans in the centre of technological developments."

Also in the new Dutch ICT research agenda, the human has entered the loop. In the research themes, "De Data-explosie", "Digitale Beleving", en "Intelligente Systemen", the challenge to design technology with the human user in mind is recognized. Among the long term challenges for intelligent systems, interactions with users come first: "De grote uitdagingen op de lange termijn van intelligente systemen zijn de samenwerking tussen deze slimmer, adaptiever en autonomer wordende systemen en de mensen die ze gebruiken."

The European Union has always had a strong interest in promoting the use of ICT for creativity and personal development. The creative industries have also become an important domain in ICT research in the Netherlands, witness several recent initiatives (NWO, NOAG-ict, Dutch Entertainment Computing Consortium, GATE). The interest for entertainment, art, (new) media, design and games is another way in which technology has to care about the user experience.

### ***3.b. Programme development***

The Computer Mediated Environments considered in NICE and in HMI range from ambient intelligent environments to worlds created in virtual reality. Whereas in the ambient vision the computer disappears into the background and the interaction with technology is envisaged to become completely "unmediated", the medium superimposes on the real natural environment in virtual reality. From Virtual to Ambient Environment there is thus a complete scala of interaction strategies and techniques to be studied.

The research questions in NICE have been gathered around four research topics: multi-media, human interaction, synthetic environments and games. Presently, HMI research concentrates on the first two topics. The two research topics on which HMI concentrates are multimedia and human interaction.

#### ***Multi-Media***

According to the NOAG-ict on the "Data-explosion" research theme, the last step in controlling the data-explosion should be directed at the interaction with the users; mid-term research should make it possible for information retrieval and information visualisation to use the relation between datamanagement and datamining to improve the access to data and provide users with better navigation tools. Personalised presentations and summaries could improve the digital experiences of many users.

- Indexing and semantic access;
- Context-aware retrieval;
- Context-aware presentation;
- Question-Answering: multimedia queries and;
- Information fission and multi-media presentations;
- Personalisation.

Within this research topic there is close cooperation with the other research groups in the CTIT SRO NICE.

#### ***Human Interaction***

An important aim for research that looks into "natural" modes of interaction has always been to design intelligent systems that can analyse and interpret the communication channels that humans naturally use. Speech and natural language understanding is therefore also on the NICE research agenda. However, there are many other modes and channels through which humans communicate with each other and interact with their environment. The challenge for the next generation systems that look into processing human interaction will need to go

beyond the borders of traditional computational linguistics research and deal with (1) other modes of communication such as nonverbal displays, and (2) other dimensions of content beside propositional information but including propositional attitudes (certainty-doubt), liking, and emotion (see also NOAG-ict). There are various situations for which answers to major research questions are beneficial: for understanding user actions in ambient environments, for the collection and retrieval of human communication situations (meeting memories, personal digital memories), for computer supported communication and for traditional human computer interaction, where the mental state of the user can be inferred from his or her actions.

#### *Synthetic environments and Games*

As mentioned, in the period 2002-2005, synthetic environments and games have not yet received sufficient attention. Nevertheless, virtual environments have been created and research, in particular related to properties and effects of the behavior of virtual humans in such environments has been performed. In the period 2006-2010 our aim is to put more efforts in research and development on casual games, games that adapt to the mental state of the user and games that allow controlled brain activity input from the user. In particular we want to investigate bodily interaction, interaction that allows input from physiological processes, input from gestures, body postures, speech and facial expressions, and, to investigate in the period 2007-2010, input from measured brain activity. In our research in the direction of brain-computer interfacing the assumption will be that BCI is a subset of CHI. Measuring and monitoring brain activity makes it possible to evaluate a particular interface (including its interaction modalities) and possibly redesign it, and to adapt the interface to the affective state of a particular user. Direct control of the interface using brain-controlled input, together with other input modalities, is a research direction we want to explore.

#### **4. Processes in research, internal and external collaboration**

All PhD students are supervised by an academic. All papers written by PhD students are read and extensively discussed with staff members of the group. Each PhD student is expected to co-author two or three scientific publications every year. Ph.D. students that have been appointed in national and international research projects generally have no problem to fulfill this expectation.

There is much cooperation between staff members since they often work on the same (externally funded) projects. This means that there are often joint visits to national and international project meetings and workshops and that most of our research papers have several staff members as authors. HMI is very active in organizing scientific and teaching events. Students of the Masters Human Media Interaction are stimulated to actively participate in these events and they are asked to present their student research. Ph.D. students help in advising HMI Master students and when possible research of Master students is in the domain of interest of Ph.D. students. Publications that are 'co-authored' by Master students are no exception.

#### **5. Academic reputation (we mention highlights only, omitting PC membership etc)**

*Prof.dr. F.M.G. de Jong*

- preparatoring committee Flemish-Dutch research programme for digital archiving,
- board Dutch Research Council for the Humanities (NWO Gebiedsbestuur Geesteswetenschappen),
- board Taal- en Spraaktechnologie (Taalunie),
- steering committee CLEF (Cross-Language Evaluation Forum; activity of NoE for digital libraries DELOS),
- board NWO-programme IMIX (Interactive Multimodal Information Extraction; chair),
- expert/panelist/reviewer EU FP6,
- committee Investeren NWO Geesteswetenschappen,
- EU/NSF working group Spoken Word Archives

*Prof.dr.ir. A. Nijholt*

- In the period 2002-2005 co-chair three ACM-CHI workshops, program co-chair of IFIP
- International Conference on Entertainment Computing 2004, program chair of Social Intelligence
- Invited speaker at various conferences and meetings.
- Member of panels and roundtables during conferences.
- Reviewer for Swiss, Belgian and Austrian research funding councils.
- Invited participant of EU FP7 preparatory meetings.
- Member of the NWO VIEW (Visual Interactive Effective Worlds) committee and founding member of DECC (Dutch Entertainment Computing Community).
- Member of IFIP WG 14 committees.
- Member of the review committee of the International Graduate School in Information and Communication Technology of Trento (Italy).
- Member of the advisory committee of the JFS Ph.D. research school in Eindhoven and the Masters programme Media and Knowledge Engineering of the Technical University of Delft.
- Guest-editor of the journals Theoretical Computer Science and Artificial Intelligence for Society.
- Member of the Board of the EU AMI (Augmented Multi-party Interaction) Consortium.
- Member of the managing committee of COST2102.
- Member editorial board of the Kluwer journal Grammars (until 2004).
- Received in 2005 the title of distinguished visitor of the city of Santiago de Cuba for his efforts to promote computational linguistics research.
- Member editorial board of the Kluwer journal Grammars (until 2004).

## 6. External validation

### *6.a. Societal relevance*

Our work is targeted at a variety of applications, ranging from providing access to the daily broadcast-news (8-uur Journaal) and cultural heritage archives from the Second World War to user support in smart homes and smart meeting environments and entertainment applications. In our smart environment research we aim at supporting meeting participants during a business meeting and allowing off-line access to captured meeting activities. Technology transfer is an important aim of our research. Together with our European research partners we have initiated and participated in technology transfer events in Brussels and Amsterdam. Our research on multimodal interaction has been visible in various entertainment applications that have been shown at several public events in and outside Europe. Close relations with several small local companies, sometimes run by our ex-students, help to transfer our research results and approaches to these companies. In recent years we have demonstrated our research at CeBIT (Hannover) and Wainhouse Research European Forum in Berlin.

### *6.b. Industrial contacts*

Small, medium-sized and large companies/organisations in the areas of

- Multimedia (NOS, NOB, Beeld en Geluid, TNO ICT, Medialab, Carp Technologies, TeleCats, ParaBots)
  - Image processing, graphics & virtual reality (re-lion, VicarVision, Kunst&vanLeerdam))
  - Games & simulation (Green Dino, Engine Software, Playlogic)
  - Usability testing (Noldus, IBM, TNO Human Factors)
  - Interaction & presentation technology (Oce Research, Telematica Instituut, Philips, Forward Thinking, Q-go Nederland)
  - Smart environments (Home Automation Europe, TalkingHome, Spiderfone, VisualNexus)
  - Publishing companies (PCM, Van Dale Lexicografie)
  - Stichting Notas (group of SMEs with focus on applications of language engineering)
  - Libraries/archives (Koninklijke Bibliotheek, dbnl, Gemeentearchief Rotterdam)
- Membership of industrial bodies (Franciska de Jong): (1) advisory board Van Dale Lexicografie (chair), (2) advisor/reviewer Senter, (3) supervisory board Q-go Nederland BV



**7. Researchers and other personnel ("wp")***Table 4*

Name and present title		2003	2004	2005
professor (hgl)	Jong, Prof.dr. F.M.G. de	0,24	0,25	0,26
	Nijholt, Prof.dr.ir. A.	0,4	0,4	0,4
associate professor (uhd)	Zwiers, Dr. J.	0,4	0,4	0,4
assistant professor (ud)	Akker, Dr.ir. H.J.A. op den	0,4	0,4	0,4
	Asveld, Dr.ir. P.R.J.	0,4	0,4	0,4
	Dijk, Dr. E.M.A.G. van	0,4	0,4	0,4
	Heylen, dr. D.K.J.	0,4	0,4	0,4
	Kuper, Dr.ir. J.	0,4	0,4	0,4
	Poel, Dr. M.	0,4	0,4	0,4
	Vet, Dr. P.E. van der	0,4	0,4	0,4
<b>Total tenured staff</b>		<b>3,84</b>	<b>3,85</b>	<b>3,86</b>
professor (hgl)	Huibers, prof.dr. T.W.C.	0,08	0,09	0,09
	Roosendaal, prof.dr. H.E.	0,06		
associate professor (uhd)	Ruttkey, dr. Z.M.		0,09	0,17
assistant professor (ud)	Theune, dr. M.	0,28	0,34	0,34
postdoctoral fellows	Hessen, Dr. A.J. van	0,4	0,42	0,42
	Ordelman, Drs. R.J.F.	0,21	1,0	1,0
	Schooten, dr.ir. B.W. van		0,28	0,84
	Theune, dr. M.	0,14		
junior staff (aio, oio, moz-p)	Bachvarova, Msc. Y.S.			0,6
	Bosma, W.E.	0,04	0,8	0,8
	Bui, H.T.		0,13	0,8
	Bui, T.D.	0,8	0,8	
	Froon, Drs. J.M.	0,08		
	Hauff, C.			0,17
	Herder, E.	0,8	0,8	0,8
	Huijbregts, ir. M.A.H.		0,33	0,8
	Jamroga, W.J.	0,8	0,53	
	Jovanovic, N.	0,8	0,8	0,8
	Keizer, S.	0,43		
	Kiss, S.	0,37		
	Kulyk, O.			0,2
	Malchanau, A.V.	0,8	0,8	0,8
	Ordelman, Drs. R.J.F.	0,5		
	Otterlo, Ir. M. van	0,8	0,53	0,63
	Poppe, ir. R.W.			0,6
	Reidsma, Ir. D.	0,17	0,67	0,67
	Rienks, R.J.	0,2	0,8	0,8
	Schooten, dr.ir. B.W. van	0,2		
	Snoek, Ir. M.	0,56		
	Trieschnigg, ir. R.B.			0,13
	Wassink, I.			0,2
other junior staff (moz, twaio)	Hofs, ir. D.H.W.		0,67	0,67
	Melis, ir. P.E.C.	0,5		
	Oinonen, K.M.			0,26
	Poppe, ir. R.W.			0,19
	Reidsma, Ir. D.	0,24		
	Welbergen, ir. H. van			0,11
<b>Total non-tenured staff</b>		<b>9,27</b>	<b>9,87</b>	<b>12,88</b>
<b>Total Research staff HMI</b>		<b>13,11</b>	<b>13,72</b>	<b>16,74</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

### 8.b. FTE-funding PhDs/postdocs

Table 5

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	65%	31%	21%	39%
Research funds	0%	12%	15%	9%
Contracts	34%	57%	65%	52%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

<i>Name project</i>	<i>Start date</i>	<i>End date</i>	<i>Sponsor</i>
AMI: Augmented Multi-party Interaction	1-1-2004	31-12-2006	European Commision
COST292 - Semantic Multimodal Analysis of Digital Media	19-8-2005	26-10-2008	European Commision
DELOS: Network of excellence on digital libraries	1-10-2000	1-10-2003	European Commision
ECHO: European CHronicles On-line	1-2-2000	1-4-2003	European Commision
EUNITE: European network on intelligent technologies for smart adaptive systems	1-1-2001	1-1-2004	European Commision
HAHAcronym: Humorous Agent for Humorous Acronyms	1-5-2001	27-2-2003	European Commision
HUMAINE: Human-Machine Interaction Network on Emotion	1-1-2004	31-12-2007	European Commision
M4: MultiModal Meeting Manager	1-3-2002	1-3-2005	European Commision
MUMIS: Multimedia Indexing and Searching Environment	1-7-2000	31-12-2003	European Commision
NiSIS: Nature-Inspired Smart Information System	1-2-2005	1-2-2008	European Commision
SAFIR: Speech Automatic Friendly Interface Research	1-3-2004	1-3-2008	European Commision
Stevin/D-COI: Dutch Language Corpus Initiative	1-6-2005	1-8-2006	Nederlandse Taalunie (Stevin)
SPRAAK: Speech Processing, Recognition and Automatic Annotation Kit	1-12-2005	1-4-2007	Nederlandse Taalunie (Stevin)
Angelica: A Natural-Language Generator for Embodied, Lifelike Conversational Agents	1-3-2003	1-3-2007	NWO Meervoud
IMIX/IMOGEN: Interactive Multimodal Output Generation	15-12-2003	15-12-2007	NWO
IMIX/VIDIAM: Dialogue management and the visual channel	1-9-2004	1-9-2007	NWO
IMIX: Technische integratie	1-1-2005	1-1-2007	NWO
Persoonlijke assistent voor mobiele webdiensten	1-7-2001	31-12-2005	SENER
PIDGIN Zelflerend Cross Lingual Interface	1-4-2002	31-12-2004	SENER
Waterland: Workflow with semi-Automatic meTadata Extraction for fully digital media pRoduction in the NetherLANDs	1-6-2001	1-6-2005	SENER
BioRange: A research programme to shape the future for bioinformatics in the Netherlands	1-1-2004	1-1-2009	SENER / BSIK
ICIS: Interactive Collaborative Information Systems	1-1-2004	1-1-2010	SENER / BSIK
MultimediaN/N5: Semantic access	1-1-2004	1-1-2009	SENER / BSIK
DRUID: Multimedia Indexing & Retrieval on the basis of Image Processing & Language and Speech Technology	1-7-2003	30-9-2003	Telematica Instituut
Spellingcheckers	1-4-1998	1-4-2003	Van Dale Lexicografie BV

## 9. Overview of the results

### 9.a. Description of scientific results

### 9.b. Key publications

Table 7

nr	Title
1	D.K.J. Heylen, A. Nijholt and H.J.A. op den Akker. Affect in Tutoring Dialogues. Journal of Applied Artificial Intelligence 19(3-4), 287-310, 2005, ISSN: 0883-9514.
2	Z.M. Ruttkay and H. Noot. Variations in Gesturing and Speech by GESTYLE. International Journal of Human-Computer Studies, 62(2), 211-229, 2005, ISSN: 1071-5819.
3	W.J. Jamroga and W. van der Hoek. Agents that Know How to Play. Fundamenta Informaticae 63 (2-3), 185-219, 2004, ISSN: 0169-2968.
4	A. Nijholt. Where computers disappear, virtual humans appear. Computers and Graphics, 28(4), Elsevier, 465-476, 2004, ISSN: 0097-8493.
5	M. Theune, D. Heylen & A. Nijholt. Generating Embodied Information Presentations. Chapter 3 in: Multimodal Intelligent Information Presentation. Kluwer Series on "Text, Speech and Language Technology", Vol. 27, O. Stock & M. Zancanaro (Eds.), Kluwer Academic Publishers, 2005, 47-70, ISBN: 1-4020-3049-5.

### 9.c. Numerical overview of the results in a fixed format of categories

Table 8

		2003	2004	2005
1 Academic publications	a. PhD-theses	4	4	1
	b. in refereed journals	8	7	8
	c. international conference proceedings	39	33	62
	d. books			
	e. book -chapters	2	3	3
<b>Total</b>		53	47	74
2. International patents				

### 9.d. Full outcome list

#### 2003

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- Ruttkay, Z.M. , Konijn, E., Hondorp, G.H.W. Differences between poker-faced and affective, 'real' and 'virtual' news readers. AAMAS'05 Workshop on Creating Bonds with Humanoids (2005, juli 25).
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- Theune, M. , Ham, R. ten, Heuvelman, A. Can you teach an old dog new tricks? How older adults perceive embodied agents. Ninth Annual SIGCHI.NL Conference, Den Haag (2005, oktober 13). 4 pp.

- Trieschnigg, R.B. , Kraaij, W. Hierarchical topic detection in large digital news archives. Proceedings of the Fifth Dutch-Belgian Information Retrieval Workshop (DIR2005) (2005, januari 10). (pp. 55-62) Utrecht Center for Content and Knowledge Engineering ISBN: 90-393-0031-3
- Trieschnigg, R.B. , Kraaij, W. Scalable hierarchical topic detection: exploring a sample based approach (extended abstract). SIGIR '05: Proceedings of the 28th annual international ACM SIGIR conference on Research and development in information retrieval, Salvador, Brazil (2005, augustus 15). (pp. 655-656) New York ACM Press ISBN: 1-59593-034-5
- Vanca, R. , Ruttkay, Z.M. A Real-Time Animation Engine for H-anim Characters. Third Hungarian Graphics and Geometry Conference (2005). (pp. 169-175) Budapest, Hungary ISBN: 963-421-593-9
- Wassink, I. , Dijk, E.M.A.G. van, Zwiers, J., Nijholt, A. Bringing Hollywood to the Driving School: Dynamic Scenario Generation in Simulations and Games. International Conference on INTElligent TEchnologies for interactive enterTAINment (INTETAIN 2005), Madonna di Campiglio, Italy Lecture notes in artificial intelligence Entertainment: First International Conference, 3814, (2005, november 30 / 2005, december 2). (pp. 288-292) Berlin Springer ISBN: 3-540-30509-2 / ISSN: 0302-9743
- Welbergen, H. van , Nijholt, A., Reidsma, D., Zwiers, J. Presenting in Virtual Worlds: Towards an Architecture for a 3D Presenter explaining 2D-Presented Information. International Conference on INTElligent TEchnologies for interactive enterTAINment (INTETAIN 2005), Madonna di Campiglio, Italy Lecture notes in artificial intelligence LNAI, 3814, (2005, november 30 / 2005, december 2). (pp. 203-212) Heidelberg, New York Springer ISBN: 3-540-30509-09 / ISSN: 0302-9743

#### *Books - chapter*

- Heylen, D.K.J. , Es, I. van, Dijk, E.M.A.G. van, Nijholt, A. Controlling the Gaze of Conversational Agents. Natural, Intelligent and Effective Interaction in Multimodal Dialogue Systems Text, Speech and Language Technology nr: 30, (2005). (pp. 245-262) Dordrecht Kluwer ISBN: 1-4020-3932-8
- Nijholt, A. The Gulliver Project: Performers and Visitors. Digital Applications for Cultural and Heritage Institutions (2005). (pp. 285-292) Aldershot, Hants, England Ashgate Publishing Ltd ISBN: 0-7546-3359-4
- Theune, M. , Heylen, D.K.J., Nijholt, A. Generating Embodied Information Presentations. Multimodal Intelligent Information Presentation Text, Speech and Language Technology nr: 27, (2005). (pp. 47-69) Dordrecht Kluwer ISBN: 1-4020-3049-5

### **10. SWOT-analysis (excluding SWOT items already mentioned in part A)**

#### *Strengths*

- Ability to attract external funding.
- Many and strong industrial contacts.
- Cohesion and flexibility.

#### *Weaknesses*

- Insufficient ambition to grasp possible opportunities.
- Average age of staff members is too high.

#### *Opportunities*

- Ambient Intelligence and smart environments are hot topics, which will lead to many HMI applications in home, office and industrial environments.
- Economic interest in the Creative Industry provides opportunities in entertainment computing, pervasive gaming and gaming in general.

**Title of the chair's program:**

Information Systems (IS)

**Sub-programmes or themes:** Requirements engineering, Architecture design, Security, Business Process Management**NABS code:** N07**Chairman:** Prof.dr. R.J. Wieringa**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal co-operations:** none**1. Mission statement**

One of the core challenges in realizing information systems (IS) is to align them to the requirements of business processes and business goals. Our mission is:

**'To develop methods, concepts and tools for the design of architectures of business software in relation to its business context'.**

By "business" we mean organizations that exist for profit as well as non-profit reasons. This includes governmental organizations, healthcare organizations, or loosely organized user groups with a shared interest. Examples of business software are enterprise IS and ERP systems, but also mobile IS and ambient intelligence systems. All these systems have in common that their requirements arise from a business context and their architecture cannot be designed independently from the architecture of the business. In this context, numerous challenges arise including requirements identification, business process support, and security of business software.

**2. Leadership**

The IS group is managed by senior research staff (Wieringa, Reichert (since Oct. 2004), van Eck), with consultation of other group members if required. The IS management team (MTIS) meets on a weekly basis, and takes responsibility for strategic, tactical and operational issues. Meetings with all academic staff members and PostDocs involved in lecturing take place twice per year.

We have established well-defined procedures, rules and quality constraints with respect to project acquisition, project management, scientific publications, research assessment, and PhD student supervision. For repetitive tasks, in addition, coordinators have been nominated.

Senior staff members have been involved in external boards and committees at both the national and international level. In particular, we try to influence the definition of external research programmes (e.g., FP6, NIRICT, and NWO) in order to fulfill our overall vision. We maintain an excellent network with partners from academia and research at the local, national and international level. These activities have resulted in numerous research collaborations and successful acquisition of external funding. Finally, IS group members have published high quality papers in top conferences and journals. Altogether this success in research has provided an intrinsic motivation for staff members to continue with our acquisition activities and to further extend research collaborations.

M. Reichert is acting as coordinator of the CTIT SRO *E-health*; this constitutes one of the largest multidisciplinary research groups working on e-health in the Netherlands. The synergy created by this coordination activity has also contributed to the success of the IS group; the same applies with respect to our PostDocs who have participated in the SRO A-Services Internet and the SRO Istrice.

### 3. Strategy and policy

#### 3.a. Design in brief

**Context and mission of our research:** Large organizations operate in networks of profit-and-loss responsible actors, be they business units inside a holding or independent businesses in a value chain. In all these situations, IS have to securely cooperate across organizational boundaries with partners, subcontractors, suppliers and customers. This creates hard problems in the area of interoperability, the alignment between processes within an organization as well as across business boundaries, and the secure information exchange with other companies.

Our mission is to develop methods, concepts, and tools for the cost-effective design and management of IS in large organizations operating in networks. Practical problems these areas involve an intricate interplay between software-based service provisioning, business process support, business semantics of software, and security aspects. As indicated in the following diagram, we restrict ourselves to the alignment of business and IT in these areas.

	Services	Processes	Semantics	Security
Business				
Business software: enterprise systems, ERP, Aml, mobile information systems				
Software infrastructure				
Physical entities				

**Brief description of research areas:** Alignment of business and IT is a design question with two parts how do we identify business requirements and how do we design a matching IT architecture—our first two research themes. Two aspects of these questions get our special attention: How to design adequate IT services and business process support, and how to provide secure IT support for the business—our third and fourth research themes. We investigate these themes in a coherent way and projects in one of these themes often spill over into another of these themes.

- *Requirements Engineering (RE):* RE addresses the problem of aligning IT with the goals of a business. It is about analyzing properties of the problem for which an IT solution is sought, and determining which properties this solution should have. Examples of IT solutions include enterprise IS (e.g., ERP systems), but also mobile IS and ambient intelligence systems (AmI). In our RE research we have addressed the following challenges: architectural modelling utility for service enabling, RE in smart surroundings, modelling control aspects of embedded systems, quality-driven RE, and value-driven intermediation pattern synthesis.
- *Architecture design:* While RE deals with methods to discover the desired properties of IT solutions themselves, our architecture research focuses more on the methods, tools and techniques needed for integrating IT solutions within organizations. As indicated this constitutes a complex task requiring the configuration of sometimes hundreds of packages, the integration of these packages with each other and with legacy software within and across company boundaries, and the integration with the business and the coordination processes in the different companies. Challenges we have addressed in our architecture research: design of guidelines for architectural alignment, value-base IT alignment, quality indicators in design space, cost estimation of cross-organizational ERP systems, collaborative alignment of cross-organizational ERP systems, and semantic interoperability of enterprise processes.



- *Business Process Management (BPM)*: In modern networked organizations, IS are integrated with process management systems. The resulting "process-aware" IS must offer a sufficient degree of flexibility to cooperate with partners on short notice, without compromising the efficiency of the business and the coordination processes needed for this. This requires advanced techniques and tools which enable quick, accurate and intelligent decisions, and which allow modifying business processes on the fly, learning from these process changes, dynamically allocating resources, etc. On the one hand our BPM research has dealt with core issues related to the design of next generation process management technology (e.g., support of adaptive workflows, data-driven workflows); on the other hand we have studied processes from advanced application domains (e.g., car engineering and healthcare) in order to elaborate more sophisticated requirements for future process management systems.
- *Security*: Cross-organizational systems bring with them new security problems, because the policy and security models and their implementations are different across organizations. To date, security has been viewed as a problem of regulating access to digital or physical spaces. To face the challenges of security in cross-organizational systems, we need to provide an integrated view of security that spans the digital and physical domain, and can relate this to business-level security policies. Because total security is impossible, the approach must take a risk management perspective. Our security research has addressed the following topics: integrated policy-based intrusion detection, integrated security and privacy in a networked world, and next generation methods, tools and techniques for the protection and security of content.

*Research approach*: We do empirical as well as design-oriented research. Examples of empirical re-search are case study research and field studies. Examples of design-oriented research are action re-search, experimental prototyping and research in software specification notations. In general, our aim is to investigate real-world problems, to design solutions, and to validate these solutions. We therefore perform our research in close cooperation with companies, such as banks, insurance companies, government organizations and health care organizations. Because of the close coherence of our research themes, there several permanent staff members working on each theme, and conversely each permanent staff member contributes to more than one theme.

### **3.b. Programme development**

For each of the four themes described above we have identified short-term and long-term challenges which will drive our future research and programme development:

- *Requirements engineering*: Five years from now, we should have a sound understanding of how business goals, business processes, and IT support should be aligned across organizational boundaries. For this purpose we are developing techniques to analyze business goals and value propositions to produce matching goal models and value models, and map these onto process models and IT, new or legacy. In ten years from now, we should have transformed IS design into a real engineering discipline. This means that we should be able to predict the effect of different design choices on the problems to be solved, and be able to quantify this in terms of measures that indicate to which extent certain goals can be reached.
- *Architecture design*: Five years from now, we should have developed techniques that allow us to represent business goals and service delivery in a network of businesses in such a way that these can be related to the coordination processes and the IT architecture needed to implement this cooperation. These techniques must be independent of the implementation platform to be used. Ten years from now, we should be able to better estimate the cost and benefit of different architectural choices. So far, there exist no reliable cost estimation techniques in this context. Traditional software engineering cost estimation models do not suffice in this situation. We will look into the use of various techniques, such as real-options analysis, to define sound cost-estimation techniques.

- *Business Process Management:* Five years from now, there will be the rise of the agile enterprise being able to rapidly set up new business processes and to quickly adapt existing ones to changes in its environment. Our BPM research contributes to this development. Ten years from now, process management technology should also provide support in smart environments, knowledge-intensive settings (e.g., healthcare), etc. Distributed and mobile work-flows will interact with their environment, automatically adapt to changing or exceptional situations, and communicate with back-end systems (and other workflows) only if needed. The challenge is to provide a conceptual framework and to develop next generation technology which enables dynamic and adaptive processes in a variety of settings.
- *Security:* Five years from now, security will be considered the number one factor prohibiting further IT-supported productivity growth and the number one factor withholding application of all kinds of new technology. The challenge is to develop methods and tools that enable having a more objective understanding of security risks involved in IT applications. Ten years from now, the complexity crisis should be in the process of being solved in the usual way: by disintegration of the IT supply chain. IT security will have become a specialists' job provided by specialists companies. More than for any other sub discipline of CS, for security an absolutely necessary condition is that it is fully understood how security can be 'factored out' in IS and in the information infrastructure. The challenge is to develop theories, methods and tools to understand and manage the relation between security and other aspects of IT. As an aside, the security profession is organized in the same way as the auditing profession is today.

Large parts of our research on RE, architectural design, and BPM are part of the CTIT Strategic research Orientation (SRO) A-SI (*A-Services Internet*). Our security research is part of the SRO Istrice. We are involved in several healthcare related projects (e.g., process support in healthcare, privacy in healthcare networks) which are part of the *SRO E-health*. In the NIRICT, our research activities are part of the strategic research agenda (SRA) EIS (enterprise information systems) and of the SRA security.

#### 4. Processes in research, internal and external collaboration

The IS group has established well-defined procedures, rules and quality constraints with respect to project acquisition, scientific publications, research assessment, and PhD student supervision. Each PhD student is supervised by a senior research staff member, often with assistance of a PostDoc. Typically, there are several PhD students working in one programme, which creates synergy effects. We place these students in one room, which fosters collaboration and information exchange. Several of our projects involve partners from other groups and universities, which provides additional exchange channels for our students. We are guiding our PhD students in publishing their research results in high-quality journals, conferences and workshops. Furthermore, PhD students, PostDocs, and senior research staff periodically report about their work in our IS seminar. This event takes place weekly and constitutes a forum for discussing and exchanging research ideas and results. We provide a variety of opportunities to our PhD students to strengthen their research skills. This includes a reading club, a seminar series with external speakers, and courses on different topics (e.g., SIKS, technical writing).

Members of the IS group have a strong background in mathematics, computer science, and business information technology. We are an international group with people from 10 countries. About 45 % of the research staff and PhD students are female. We are funding at least one Dutch language course for each international staff member in order to ease integration.

## 5. Academic reputation (we mention highlights only, omitting PC membership etc)

*Prof. Dr. Roel Wieringa*

- Scientific Director of the School of Information and Knowledge Systems (SIKS; [www.siks.nl](http://www.siks.nl))
- Associate editor in Chief of IEEE Software (since 2004)
- Editorial board, Requirements Engineering Journal
- Editorial board, Journal of Software and Systems Modelling
- Editorial board, Int'l Journal of Web Engineering and Technology (IJWET)
- Chair of the Requirements Engineering Conference Steering Committee
- Member of the board of the Nederlands Architectuurforum (NAF; [www.naf.nl](http://www.naf.nl))
- Member of the board of governors of SIKS
- Member of the scientific advisory board of CARE ([www.care-t.com/company/sab.asp](http://www.care-t.com/company/sab.asp)).
- Member of the advisory board, Delft-TopTech (<http://www.delft-toptech.nl>)
- Conferences:
  - Program chair of the IEEE Requirements engineering conference (2003)

*Dr. Manfred Reichert*

- Member of the board of GI SIG EMISA (Special Interest Group on Development Methods for Information Systems and their Application)
- Editor in Chief of EMISA Forum (since 2006)
- Conferences & Workshops:
  - Co-chair and Co-organizer of the Annual Conference of the German Computer Society (GI), 2004
  - Co-chair of the GI Workshops on Enterprise Application Integration (EAI'04, EAI'05)
  - Co-chair of the DPM'06, Proflex'06 and TCoB'06 international workshops
- IFIP TC2 Manfred Paul Award for "Excellence in Software Theory and Practice" (2005)

## 6. External validation

### 6.a. Societal relevance

In our vision, IT is a means to an end, not a goal in itself. We see our societal relevance in developing techniques, methods and tools that enable organizations to better match IT with their goals. By disseminating our research results, we strive to enable organizations to employ IT in a more effective and efficient way. We use several channels for this: advisory boards (with members from companies and government) in our projects, case study and action research carried out in businesses, participation in knowledge exchange networks with practitioners and professionals (NAF, NGI), publications in professional journals and the trade press (Informatie, Automatisering Gids), and last but not least: around 30 M.Sc. projects per year in companies and governmental organizations.

*Requirements Engineering* by its very nature directly addresses the problem of matching IT with the goals of users. While RE focuses on methods to discover the desired properties of IT solutions themselves, our research on *architectural design* and *security* focuses more at the methods, tools and techniques needed for integrating IT solutions within organizations. This is a difficult problem, which has been recognized as such by major Dutch companies. They address this problem not only internally (in a number of cases with the help of our M.Sc. students), but also in knowledge exchange networks of many forms, i.e. professional associations. This enables us to directly contribute to society by playing an active role in these networks. Finally, our *BPM research* is motivated by the fact that organizations are interested in becoming more productive, while keeping or improving the quality of the services they provide to society. The way forward, as leading business thinkers show, is to focus on improving the processes executed in organizations. For instance, this is very visible in e-health. In this area, we apply BPM techniques together with network organizations active in the healthcare area to streamline healthcare processes. Our hope and belief is that this results at a higher quality of life for patients and less cost for our society.

### 6.b. Industrial contacts

- Companies and organizations participating in our projects: *DaimlerChrysler Research, ABN AMRO, Atos Origin, Belastingdienst C/ICT, BiZZdesign, Cap Gemini, CIBIT/SERC, Cisco Systems, Deloitte, Fox-IT, Gartner, GetronicsPinkRocade, HP, IBM Netherlands, ICTU, KLM, KPN, Labyrint, Medical Informatics Group / University of Marburg, MST Enschede, OrangeWing Consulting, OptIn Solutions, Ordina, Rabobank, Sogeti, Telindus, TNO, Twynstra Work Innovation, Unisys, VisionFlow*
- Companies and organizations where we have had M.Sc. students (and which are not contained in the aforementioned list): *AINO, Akzo Nobel Car Refinishes, BeValue, British Telecom, Cordys, Drankenpallet Beheer Nederland, eMAXX, Fortis Bank Nederland, Hoofdbedrijfchap Afbouw en Onderhoud, InfoTopics, Interpolis, KPMG, Min. v. Financien, Newtel, NIB Capital, Novaxon, NS Internationaal, Oce, Philip Morris, Philips, PricewaterhouseCoopers, Procter & Gamble, Raet, Refaja Ziekenhuis, Roessingh R & D, Shell, Telematica Instituut, Thales, TietoEnator (Finland), UPS, UWV, Wavin*

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Wieringa, Prof.dr. R.J.	0,4	0,4	0,4
associate professor (uhd)	Grefen, dr.ir. P.W.P.J.	0,06		
	Reichert, dr. M.U.		0,05	0,4
assistant professor (ud)	Eck, Dr. P.A.T. van	0,4	0,4	0,4
	Sikkel, Dr. N.	0,4	0,4	0,4
	Weg, Dr. R.L.W. van de	0,32		
other junior staff (moz, twaio)	Vonk, Ir. J.	0,66		
<b>Total tenured staff</b>		<b>2,24</b>	<b>1,25</b>	<b>1,6</b>
professor (hgl)	Muntslag, Prof.dr.ir. D.R.	0,04		
	Pieper, Prof.ir. R.	0,04	0,04	0,02
postdoctoral fellows	Bassil, S.			0,25
	Daneva, dr. M.		0,15	1,0
	Rinderle, dr. S.B.			0,25
	Sent, dr. D.			0,17
	Su, dr. X.			0,8
	Wombacher, A.		0,08	1,0
junior staff (aio, oio, moz-p)	Angelov, S.A.	0,14		
	Bodenstaff, L.			0,13
	Hordijk, W.T.B. drs.		0,31	0,34
	Ivanovic, A.		0,27	0,8
	Jansen, dr. D.N.	0,4		
	Kolos, L.		0,23	0,8
	Marincic, Msc. J.			0,54
	Muller, D.			0,37
	Nunes Leal Franqueira, V.			0,34
	Pumareja, D.T.	0,8	0,8	0,53
	Santana Tapia, R.G.			0,54
	Zarvic, Msc. N.			0,44
	Zlatev, Z.V.	0,8	0,8	0,8
other junior staff (moz, twaio)	Krukkert, D. ir.		0,8	
<b>Total non-tenured staff</b>		<b>2,22</b>	<b>3,48</b>	<b>9,12</b>
<b>Total Research staff IS</b>		<b>4,46</b>	<b>4,73</b>	<b>10,72</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

The IS group is well equipped to perform the research described.

### 8.b. FTE-funding PhDs/postdocs

Table 5

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	100%	69%	47%	72%
Research funds	0%	0%	22%	7%
Contracts	0%	31%	31%	21%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

<i>Name project</i>	<i>Start date</i>	<i>End date</i>	<i>Sponsor</i>
COREPRO: Configuration-based Release Management Processes	1-7-2005	31-12-2007	DaimlerChrysler Research
Process Support for the Automotive Sector	1-3-2005	1-9-2005	DaimlerChrysler Research
Process Visualization and Transparency	1-3-2005	1-9-2005	DaimlerChrysler Research
COOP: Coordination Process Correctness and Trust Assumptions	1-11-2005	1-11-2009	NWO
MOCA: Modeling Control Aspects of Embedded Systems	1-5-2005	1-9-2009	NWO
PROSE: Process Support in E-Health	1-10-2004	1-10-2007	NWO
VITAL: Value-based IT ALignment	1-5-2005	15-6-2009	NWO
QUIDS: Quality Indicators in Design Spaces	1-2-2004	31-1-2008	Ordina
Freeband/A-MUSE: Architectural Modeling for Service Enabling in Freeband	1-1-2004	1-1-2009	SENER / BSIK
Smart Surroundings	1-4-2004	1-10-2008	SENER / BSIK
IPID: Integrated Policy-based Intrusion Detection	1-8-2005	1-8-2009	STW
GRAAL: Guidelines Regarding Architecture ALignment	1-9-2002	31-12-2004	Telematica Instituut
SEINE: SEmantic INteroperability support for Enterprise processes	1-2-2004	1-2-2008	Telematica Instituut
Intermediation: support for negotiation and alliance formation	1-10-2001	1-3-2006	University of Twente
VIPS: Value-driven Intermediation Pattern Synthesis	2000	2005	University of Twente

## 9. Overview of the results

### 9.a. Description of scientific results

The results that we are most proud are:

- Significant advances on architecture design (GRAAL Architecture framework), in particular enabling the description of complex ICT architectures in a business
- Significant advances on modelling methods for reactive systems (the outcome of research done for ref. 2 in table 7).
- Development of one of the most advanced process management technologies (ADEPT), in particular supporting process schema evolution, ad-hoc process changes, and exception handling techniques (in close cooperation with the ULM University, Germany).
- Very insightful and consolidated findings in case studies we conducted in the healthcare and the automotive domain, particularly regarding process support in these areas.

**9.b. Key publications**

Table 7

nr	Title
1	Daneva, M., Wieringa, R.J. (2005). Requirements Engineering for Cross-organizational ERP Implementation: Undocumented Assumptions and Potential Mismatches. <i>Int. Conf. on Requirements Engineering (RE'05)</i> , Paris, Aug. / Sept. 2005, pp. 63-72, IEEE Computer Society Press.
2	Wieringa, R. (2003). <i>Design Methods for Reactive Systems: Yourdon, Statemate, and the UML</i> . Morgan Kaufmann Publishers. ISBN: 1-55860-755-2.
3	van Eck, P., Blanken, H., Wieringa, R.J. (2004). Project GRAAL: Towards Operational Architecture Alignment. <i>Int. J. of Cooperative Information Systems</i> , 13(3):235-255, 2004, ISSN: 0218-8430.
4	Rinderle, S., Reichert, M., Dadam, P. (2004). Correctness Criteria For Dynamic Changes in Workflow Systems - A Survey. <i>Data and Knowledge Engineering</i> , 50(2):9-34, 2004, ISSN: 0169-023X
5	Rinderle, S., Reichert, M., Dadam, P. (2004). Flexible Support of Team Processes By Adaptive Workflow Systems. <i>Int. J of Distributed and Parallel Databases</i> , 16(1):91-116, 2004, ISSN: 0926-8782

**9.c. Numerical overview of the results in a fixed format of categories**

Table 8

		2003	2004	2005
1 Academic publications	a. PhD-theses	1		
	b. in refereed journals	3	4	4
	c. international conference proceedings	16	20	46
	d. books			
	e. book -chapters	1	1	3
<b>Total</b>		21	25	53
2. International patents				

**9.d. Full outcome list****2003***PhD-theses*

Jansen, D.N. Extensions of Statecharts with Probability, Time and Stochastic Timing. (2003, oktober 29). 159 pp. Bern, Zwitserland Inmarks ag Thesis advisor(s): Prof.dr. R.J. Wieringa, Prof.dr.ir. J.P. Katoen. ISBN: 3-9522850-0-5

*Journal articles*

Eshuis, H. , Wieringa, R.J. Comparing Petri Net and Activity Diagram Variants for Workflow Modelling - A Quest for Reactive Petri Nets. Lecture notes in computer science LNCS 2472, (2003). (pp. 321-351) ISSN: 0302-9743

Grefen, P.W.P.J. , Angelov, S.A. Three-Level Process Specification for Dynamic Service Outsourcing: From Petri Nets to ebXML and WFPDL. Petri Net Technology for Communication-Based Systems Lecture notes in computer science 2472, (2003). (pp. 264-280) Berlin Springer ISBN: 3-540-20538-1 / ISSN: 0302-9743

Hu jinmin, H.J. , Grefen, P.W.P.J. Conceptual Framework and Architecture for Service Mediating Workflow Management. Information and software technology nr: 13, 45, (2003). (pp. 929-939) ISSN: 0950-5849

*Conference proceedings*

- Berry, D.M. , Kazman, R., Wieringa, R.J. Report about Second International Workshop on From Software Requirements to Architectures. 25th International Conference on software Engineering (ICSE 03) 25, (2003, mei 9 / 2003, mei 9). (pp. 797-798) Seattle IEEE Computer Science Press
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**10. SWOT-analysis (excluding SWOT items already mentioned in part A)***Strengths*

- We have a stable set of research themes: value-based requirements engineering, process management, security, and cost-benefit estimation of information systems
- Coherence: For each theme there is a core leader, yet all of us contribute to each theme.
- Fruitfulness: Scientific production of the group has been prolific. Our project proposal and proposal acceptance rates are high.
- Relevance: Our themes produce immediate recognition with our business partners
- We have an extensive network of business partners and we are good at speaking their language.
- We have excellent contacts to well-known researchers at both the national and the international level.

*Weaknesses*

- Prolific growth in the form of the usual small projects (1-2 Ph.D.s) leads to enormous overhead.

*Opportunities*

- We can establish a name in the Netherlands and abroad for practical approaches to the themes listed above (value-based requirements engineering, process management, security, and cost-benefit estimation of information systems) as well as in e-health. If we keep the staff in this area, we could grow further to achieve a critical mass
- The NIRICT initiative will help us to strengthen our Dutch network and to gain more influence on future research programs on enterprise information systems
- E-health is a booming area.

*Threats*

- Accounting mindset forces us to write working hours as if research can be mapped to measurable low-level tasks. This does not recognize the chaos of daily life in an academic research group

**Part II Design Cluster**

The heart of an ICT system is the software, which is complex, rapidly evolving, and costly to build and maintain. The first concern of designers is to deliver software with the required functionality at acceptable cost. We present the research of the three Computer Science groups that focus on design.

4. The ASNA group focuses on context aware service oriented design.
5. The FMT group focuses on rigour in design and verification, in the context of both software and hybrid systems.
6. The SE group focuses on reusable and composable designs.





**Title of the chair's research program:**

Architecture and Services of Network Applications (ASNA)

**Subprogrammes or themes:** none**NABS code:** N07**Chairmen:** *during the review period:* Prof.dr.eng. Dimitri Konstantas (2003-2004) / Dr.ir. Marten van Sinderen (2003-2005)**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal co-operations:** none**1. Mission statement**

Network applications are distributed software applications that use (tele-)communication networks to accomplish information exchange among the constituent application parts. Network applications offer services to their users, which can be other (network) applications, human users or physical processes. Network applications are heterogeneous, dynamically evolving, often comprising mobile application parts, and resource constrained. Network applications are increasingly context-aware, in order to automatically tune service delivery to user and system conditions.

Our mission is:

***'to foster systematic development of open interoperable networked applications and services'.***

We are specifically interested in context-aware mobile network applications. One important application domain addressed in the assessment period is e-health.

**2. Leadership**

The chair is managed by a team consisting of senior research active staff members (Van Sinderen, Ferreira Pires, and Van Halteren), with frequent informal consultation of other staff. The management team meets every week. Formal chair meetings with all academic staff take place 3 or 4 times a year. At least once a year a formal chair meeting is devoted to discussing research objectives and commitments of the chair as well as of individual chair members. The chair has been very successful in acquiring external research funding, setting up rewarding research collaborations with other research groups, and getting papers accepted in high quality workshops, conferences and journals. The chair participates in the two CTIT Strategic Research Orientations, namely A-SI (led by Van Sinderen) and eHealth. These two thematic areas in the field of respectively networked systems and e-health applications provide a larger multidisciplinary research community, in which technologies, theory and applications are considered in a broader context, resulting in collaborations that are both motivating and inspiring for individual chair members. Senior staff members are encouraged to participate at least once in a management or leadership course, to improve their skills in these areas.

**3. Strategy and policy*****3.a. Design in brief***

Currently the chair focuses on two related themes: context-aware service infrastructures and context-aware service design.

The main challenges concerning context-aware service infrastructures are the development and validation of integrated support for context-aware networked applications, where context-awareness implies the ability to automatically tune service delivery to the user and system conditions. Important properties to be considered are interoperability, quality-of-service, attentiveness, adaptability, learning capabilities (intelligence), and flexibility. Typically, such infrastructures support composition, deployment and provisioning of services on data networks. Services, in this context, are provided by computational elements that can be described, published, discovered and orchestrated. Advanced service infrastructures are open-

ended, configurable and scalable, and must provide support to an ever changing composition of application-specific services. In this scope, the chair considers requirements for context-aware applications in emerging application domains, and develops generic and configurable component services for these domains.

The main challenges concerning context-aware service design are the development of reference architectures and design methods that help mastering complexity of context-aware systems. Mastering complexity can shorten the design cycle of context-aware services, and enhance the functionality and quality of the resulting systems. Some techniques we are investigating in relation to this theme are model-driven architecture (i.e., metamodeling and model transformations) and semantic web services (i.e., ontologies and reasoners). Context-aware service designers typically have to be aware of available context-aware service infrastructures and components, in order to foster re-use and profit from proven solutions.

Results from both themes are applied in and specialized for the e-health application domain. In this way we have been able to validate some of our research results and show their social and economic relevance.

### ***3.b. Programme development***

This ASNA chair was officially instated in October 2004 by merging the Architecture of Distributed Systems (ARCH) chair and the Application Protocol and Systems (APS) chair.

The ARCH chair was created in 1984, with Prof.dr.ir. C.A. Vissers as chairman. When Prof. Vissers became Scientific Director of the Telematics Research Centre (later 'Telematica Instituut') in 1993, his full-time appointment changed to part-time (0.2 fte). As a consequence, the group had no full-time professor as chairman. Dr. Van Sinderen became acting chairman in 2000.

The ARCH chair has a long tradition in the development of design methods and reference architectures. The ARCH chair has contributed to a number of Dutch national projects and European (IST) projects on topics like, design methodologies for telematics systems (protocols and services) based on formal methods, business process modelling and re-engineering, and service infrastructures.

The APS chair was created in 2001, with Prof.dr.eng. D. Konstantas as chairman. When Prof. Konstantas accepted a full-professor position at the University of Geneva, Switzerland in 2004, his full-time appointment changed to part-time (0.2 fte). As a consequence, the group had no full-time professor as chairman.

The APS chair was involved in many national and European (IST) projects on telematics services and applications with emphasis on multimedia protocols for mobile and wireless applications, application-layer protocols and the application of Internet, object-oriented and wireless network technologies for mobile agents, mobile content distribution systems and mobile Body Area Networks of medical devices for m-health.

The ASNA chair combines the (partially overlapping) expertise of ARCH and APS, and builds on these with the aim of advancing theoretical and practical design knowledge and developing innovative technology solutions and integrated support for networked applications, especially context-aware mobile applications. Currently the chair works on service infrastructures for context-aware mobile (health) applications and on a design methodology for these applications with associated tool support. Technology solutions and design approaches for context-aware applications are evolving but there is still a long way to go before we can see commercially available applications that sense different forms of user context and react appropriately to context changes. A big step forward can be made if applications are defined and adapted more flexibly, and if context sources are developed and made available on a consistent possibly standard framework.

Much of the research is done by PhD students, under supervision of academic staff. Below we list the PhD students who have completed their PhD work during the assessment period. A characterization of main results is presented in section 9.a.

	<i>Infrastructures</i>	<i>Design</i>
<i>2003 (APS/ARCH)</i>	<i>Van Halteren, Wegdam</i>	
<i>2004 (APS/ARCH)</i>	<i>Diakov</i>	<i>Morales, Slagter</i>
<i>2005 (ASNA)</i>	<i>Hesselman, Parhonyi</i>	<i>Guizzardi**</i>
<i>2006* (ASNA)</i>		<i>Silva Souza, Van de Meent, Dijkman, Andrade Almeida</i>

\*PhD completed in 2005, defended in 2006. \*\* cum laude

#### 4. Processes in research, internal and external collaboration

The group aims at having at any point in time a substantial participation in a few large (often 3rd money stream) funded projects that fit the mission and research topics of the group. By this, it pursues the following goals: (i) financing a set of PhD positions on related topics underlying a common goal; (ii) establishing collaboration with external partners, thus positioning the group's research work in a broader (often multidisciplinary) context; (iii) transforming research results into useful and societal relevant products through the involvement of industry and users as project partners. The group also participates in smaller projects on topics related to the larger ones in order to create more critical mass and to increase dissemination of research results.

All PhD students are supervised by at least two staff members. Papers written by PhD students are extensively discussed and/or co-authored with the supervisors or other staff members. The group has weekly lunch presentations with all PhD students during which recent work or conference visits are discussed. PhD students in their first year are encouraged to submit a paper to a PhD student colloquium at an international conference. Such a colloquium is especially appreciated if it assigns prominent researchers as mentors to give feedback and advice regarding the presented PhD research plans.

#### 5. Academic reputation (we mention highlights only, omitting PC membership etc)

*Prof.dr.ir. Chris A. Vissers*

- Scientific director of the 'Telematica Instituut'

*Prof.dr.ir. N.J.M. Nieuwenhuis*

- Chairman of the innovation-driven research programme Generic Communication (IOP-GenCom)

*Prof.dr.eng. Dimitri Konstantas*

- Chairman of the 1st INTEROP-ESA 05 Conference, Geneva, Switzerland, 21-15 February 2005
- Chairman of the 9th International Conference on Object-Oriented Information Systems, Geneva, Switzerland, September 2003
- Expert evaluator for the Greek Ministry of Development General Secretariat of Research and Technology
- Expert evaluator for the Natural Sciences and Engineering Research Council of Canada (NSERC)
- Expert evaluator for the EU 6th FP
- Member of the MOCCA II, which is the Ericsson Think Thank on e-Health applications for wireless and mobile networks in emerging markets

*Dr.ir. Marten J. van Sinderen*

- Co-chair of 1st European MDA-IA Workshop, Enschede, 17-18 March 2004
- Program co-chair of the 8th IEEE Intl. EDOC Conf., Monterey, Cal., USA, 20-24 September 2004
- General co-chair of the 9th IEEE Intl. EDOC Conf., Enschede, 19-23 September 2005
- Co-chair of 3M4MDA Workshop, Bilbao, Spain, 11 July 2006

- Editorial board member of Enterprise Information Systems journal
- Program committee member of Freeband
- Expertise management team member of Telematica Instituut

*Dr. Luís Ferreira Pires*

- Co-chair of MDEIS Workshop, Miami, Florida, USA, 24-25 May 2005
- Co-chair of MDEIS Workshop, Paphos, Cyprus, 23-24 My 2006
- Co-chair of 3M4MDA Workshop, Bilbao, Spain, 11 July 2006

## 6. External validation

### 6.a. Societal relevance

The general societal relevance of the group's research lies in the enhancement of network infrastructures with application-oriented (including middleware) functionality, such that a range of different distributed applications can be adequately supported (and readily developed) on top of heterogeneous networks. Traditional application-oriented functionality comprises information transfer (e.g., e-mail), information sharing (e.g., WWW), information services (e.g., Web services), and business transactions (e.g., transaction services). More recently, application-oriented functionality is needed to profit from the ubiquity of devices with computing and communication capabilities and to support mobile applications. The context-aware services infrastructure research theme, introduced in section 3.a, addresses new and advanced application functionality; the context-aware services design research theme, also introduced in section 3.a, contributes to the quality of the design process and of the architecture for such functionality.

The main application domain currently targeted by the group is e-health. Within this domain the group collaborates with care centres, hospitals and insurance companies in several projects. One of the objectives here is to prevent health problems and to enable home care through tele-monitoring and tele-treatment while reducing overall costs for healthcare. A prototype for a mobile health platform has been developed, validated and applied, together with hospitals, care providers and medical systems manufacturers. In addition, based on this platform, specific support has been developed for epileptic patients, chronic pain patients, spasticity patients and women with high risk pregnancies.

### 6.b. Industrial contacts

- National: Telematica Instituut (Enschede), TNO-ICT (Delft, Groningen, Enschede), Roessingh R&D (Enschede), Compuware (Amsterdam), BiZZdesign (Enschede), Lucent Technologies Bell Labs Twente (Enschede), Thales (Hengelo), Philips Research (Eindhoven), Ericsson (Rijen), Draeger (Best), GigSoft (Amsterdam), Orbis (Sittard), MST (Enschede), TMSI (Oldenzaal), Yucat (Driebergen), Sigmax (Enschede), Menzis (Enschede).
- International: France Telecom R&D (Issy les Moulineaux, France), Telenor (Fornebu, Norway), iO (Germany), Softeam (France), IKV++ Technologies AG (Berlin, Germany), Eurescom (Heidelberg, Germany), ICOM, Ericsson (Sweden; Germany), HCPB (Barcelona, Spain), LITO Polyclinics (Cyprus), Alcatel (France; Germany), Nokia (Finland), DoCoMo (Germany), Siemens (Germany; Austria), NEC (UK), Telecom Italia S.p.A. (Italy), T-Systems (Germany), Microsoft (Germany), Telefonica (Spain), Thomson (France), VTT (Finland).

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Konstantas, prof. D.	0,09	0,03	
	Vissers, Prof.dr.ir. C.A.	0,08	0,09	0,09
associate professor (uhd)	Ferreira Pires, Dr. L.	0,4	0,4	0,4
	Pras, Dr.ir. A.	0,8	0,26	
assistant professor (ud)	Sinderen, Dr.ir. M.J. van	0,8	0,4	0,4
	Beijnum, Dr.ir. B.J.F. van	0,4	0,4	0,4
	Halteren, A.T. van	0,4	0,4	0,4
	Quartel, Dr.ir. D.A.C.	0,4	0,4	0,4
	Widya, Dr.ir. I.A.	0,4	0,4	0,4
postdoctoral fellows	Jones, Dr.ir. V.M.	1,0	1,0	
<b>Total tenured staff</b>		<b>4,77</b>	<b>3,78</b>	<b>2,49</b>
professor (hgl)	Huizer, prof.dr. E.	0,09		
	Michiels, Prof.ir. E.F.	0,05		
	Nieuwenhuis, Prof.dr.ir. L.J.M.	0,08	0,09	0,09
associate professor (uhd)	Konstantas, prof. D.			0,08
assistant professor (ud)	Aroyo, dr. L.M.	0,17	0,17	0,02
	Wegdam, dr. M.	0,02	0,09	0,09
postdoctoral fellows	Gay, V.C.J.	0,1		
	Jones, Dr.ir. V.M.			1,0
	Pereira Filho, prof. J.G.	0,75		
junior staff (aio, oio, moz-p)	Andrade Almeida, J.P.	0,8	0,8	0,63
	Boros, Msc. S.	0,8		
	Broens, ir. T.H.F.		0,32	0,8
	Diakov, Msc. N.K.	0,45		
	Dijkman, ir. R.M.	0,8	0,8	0,8
	Dockhorn Costa, P.	0,27	0,8	0,8
	Dokovski, N.T.		0,26	0,12
	Fadlisyah, M.			0,37
	Guizzardi, dr. G.	0,8	0,8	0,33
	Guizzardi-Silva Souza, R.	0,8	0,71	0,66
	Harkema, Drs. M.	1,0	0,8	0,26
	Le, Ir. M. van	1,0	0,8	0,53
	Liu, H.			0,73
	Meent, Ir. R. van de	1,0	0,8	0,8
	Mei, H.			0,4
	Morales, M.sc. J.M.	0,8		
	Parhonyi, dr. R.	0,8	0,8	0,66
	Pawar, P.			0,44
	Sheikh, K.			0,68
	Wegdam, dr. M.	0,48		
other junior staff (moz, twaio)	Dokovski, N.T.	0,54		
	Koprnikov, G.T.	0,46		
	Shishkov, dr. B.B.			0,8
	Wac, K.E.	0,25	0,08	
<b>Total non-tenured staff</b>		<b>12,3</b>	<b>8,11</b>	<b>11,09</b>
<b>Total Research staff ASNA</b>		<b>17,07</b>	<b>11,9</b>	<b>13,58</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

### 8.b. FTE-funding PhDs/postdocs

Table 5

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	31%	29%	33%	31%
Research funds	8%	0%	0%	3%
Contracts	61%	71%	67%	66%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

<i>Name project</i>	<i>Start</i>	<i>End</i>	<i>Sponsor</i>
Agent Academy: A Data Mining Framework for Training Intelligent Agents	1-11-2001	30-4-2004	European Commision
CANDLE: Collaborative And Network Distributed Learning Environment	1-6-2000	1-6-2003	European Commision
E-NEXT: Network of Excellence Emerging Networking Experiments and Technologies	1-1-2004	1-7-2006	European Commision
HealthService 24: Continuous Mobile Services for Healthcare	1-2-2005	31-7-2006	European Commision
INTEROP: Interoperability Research for Networked Enterprises, Applications and Software	2004	2009	European Commision
MobiHealth: Innovative GPRS/UMTS mobile services for applications in healthcare	1-4-2002	31-12-2005	European Commision
MODA-TEL: Model Driven Architecture for Telecommunications Systems Development and Operations	2002	2004	European Commision
X-Motion: eMobile Testbed for Interoperability of Networks in eLogistics	1-7-2002	31-12-2003	European Commision
Management of DISH applications: Provider-based Accounting	2000	2005	NWO
EQUANET: End-to-end Quality-of-Service in Next Generation Networks	1-12-2002	1-3-2005	SENER
Freeband/A-MUSE: Architectural Modeling Utility for Service Enabling	1-1-2004	1-1-2009	SENER / BSIK
Freeband/Awareness: context AWARE mobile NETworks and ServiceS	1-1-2004	1-1-2009	SENER / BSIK
Amigo: Ambient Intelligence for the Networked Home Environment	1-1-2004	1-11-2007	Telematica Instituut
ArCo: Architectural Concepts for Service-oriented Design	1-1-2003	31-12-2005	Telematica Instituut
Freeband/WASP: Web Architectures for Services Provisioning	1-8-2002	1-5-2004	Telematica Instituut
M2C: Measuring, Modeling and Cost Allocation for Quality of Service	1-6-2003	31-12-2005	Telematica Instituut
Mobile & Wireless: Mobile Applications through Wireless Communications on the Train	1-1-2004	31-12-2005	Telematica Instituut
Mobilife	1-1-2004	31-12-2005	Telematica Instituut
MOSAIC: Mobile Worker Support Environments	1-1-2004	31-12-2005	Telematica Instituut

## 9. Overview of the results

### 9.a. Description of scientific results

*Main scientific results in the assessment period are:*

- Advances in middleware technology, particularly concerning qualitative aspects, dynamic configuration, load balancing and monitoring, so that application development can be facilitated.
- Development of a model-driven methodology for context-aware mobile applications.
- Advances in service platforms for context-aware mobile applications and context modelling.
- Development of a foundational ontology to analyse, (re-)design and provide foundations for conceptual modelling languages, which is particularly applicable for networked applications and services.
- Development of service reference architectures for various application domains, especially geo-information, groupware and micropayments.
- Development and validation of a platform for mobile health applications.

### 9.b. Key publications

Table 7

nr	Title
1	Dockhorn Costa, P., Ferreira Pires, L. & van Sinderen, M. (2005) Designing a configurable services platform for mobile context-aware applications. <i>International Journal of Pervasive Computing and Communications (JPCC)</i> , 1(1): 27-37. ISSN 1742-7371
2	Almeida, J.P.A., van Sinderen, M.J., Quartel, D.A.C. & Ferreira Pires, L. (2005) Designing interaction systems for distributed applications. <i>IEEE Distributed Systems Online</i> , 6(3): 1-17. ISSN 1541-4922
3	Hesselman, C.E.W., Eertink, E.H., Widya, I.A. & Huizer, E. (2005) Delivering Live Multimedia Streams to Mobile Hosts in a Wireless Internet with Multiple Content Aggregators. <i>Mobile Networks and applications (MONET)</i> , 10(3): 327-339. ISSN 1383-469X
4	Guizzardi, G. (2005) Ontological foundations for structural conceptual models. PhD thesis, University of Twente, Enschede, The Netherlands. ISBN 90-75176-81-3
5	Konstantas, D., van Halteren, A.T., Bults, R., Wac, K., Widya, I.A., Dokovski, N., Koprnikov, G., Jones, V. & Herzog, R. (2004) Mobile Patient Monitoring: The Mobihealth System. <i>The Journal on Information Technology in Healthcare</i> , 2(5): 365-373. ISSN 1479-649X

**9.c. Numerical overview of the results in a fixed format of categories***Table 8*

		2003	2004	2005
1 Academic publications	a. PhD-theses	2	3	3
	b. in refereed journals	2	6	7
	c. international conference proceedings	16	38	42
	d. books			
	e. book -chapters		3	2
<b>Total</b>		20	50	54
2. International patents				

**9.d. Full outcome list****2003***PhD-theses*

- Halteren, A.T. van Towards an adaptable QoS aware middleware for distributed objects. (2003, januari 9). 222 pp. Thesis advisor(s): Prof.dr.ir. L.J.M. Nieuwenhuis, Dr. L. Ferreira Pires. ISBN: 90-75176-35-X
- Wegdam, M. Dynamic Reconfiguration and Load Distribution in Component Middleware. (2003, juni 26). 241 pp. Enschede Thesis advisor(s): Prof.dr.ir. L.J.M. Nieuwenhuis, Dr.ir. M.J. van Sinderen. ISBN: 90-75176-36-8

*Journal articles*

- Collis, B.A. , Jones, V.M., Veen, J.T. van der Network Applications For Group-Based Learning: Is More Better?. Interactive learning environments nr: 2, 11, (2003). ISSN: 1049-4820
- Schonwalder, J. , Pras, A., Martin-flatin, J.P. On the future of Internet Management Technologies. IEEE communications magazine nr: 10, 41, (2003). (pp. 90-97) ISSN: 0163-6804

*Conference proceedings*

- Andrade Almeida, J.P. , Ferreira Pires, L., Sinderen, M.J. van Web Services and Seamless Interoperability. Proceedings of the First European Workshop on Object-Oriented and Web services (2003). 5 pp. Darmstadt, Germany IBM Research Report series, RA220 Computer Science
- Andrade Almeida, J.P. , Sinderen, M.J. van, Ferreira Pires, L., Quartel, D.A.C. A systematic approach to platform-independent design based on the service concept. Proceedings of the 7th IEEE international Conference on Enterprise Distributed Object Computing (2003, september 16 / 2003, september 19). (pp. 112-123) IEEE Computer Society ISBN: 0-7695-1994-6
- Andrade Almeida, J.P. , Sinderen, M.J. van, Ferreira Pires, L., Quartel, D.A.C. The role of the service concept in model-driven applications development. International Middleware Conference, Workshop proceedings (2003, juni 17 / 2003, juni 17). (pp. 288-296) Rio de Janeiro PUC-Rio ISBN: 85-87926-03-9
- Andrade Almeida, J.P. , Sinderen, M.J. van, Wegdam, M., Ferreira Pires, L. Handling QoS in MDA: a discussion on availability and dynamic reconfiguration. Proceedings of the Workshop on Model Driven Architecture: Foundations and Application (MDAFA) 2003 (2003, juni 26 / 2003, juni 27). (pp. 91-96) Enschede
- Aroyo, L.M. , Mizoguchi, R., Tzolov, C.K. Ontological Approach to Courseware Authoring. The Second Wave of ICT in Education: from Facilitating Teaching and Learning to Engendering Education Reform (2003, december 2 / 2003, december 5). (pp. 1011-1014) Norfolk, USA Association for the Advance of Computing in Education ISBN: 1-880094-51-7



- Dijkman, R.M. , Andrade Almeida, J.P., Quartel, D.A.C. Verifying the Correctness of Component-Based Applications that Support Business Processes. Proceedings of the 6th ICSE workshop on Component-Based Software Engineering: Automated Reasoning and Prediction (2003, mei 3 / 2003, mei 4). (pp. 43-48) Portland, USA Carnegie Mellon University and Monash University
- Dijkman, R.M. , Quartel, D.A.C., Ferreira Pires, L., Sinderen, M.J. van An Approach to Relate Viewpoints and Modeling Languages. Proceedings of the 7th IEEE International Conference on Enterprise Distributed Object Computing (2003, september 16 / 2003, september 19). (pp. 14-27) IEEE Computer Society ISBN: 0-7695-1994-6
- Dockhorn Costa, P. , Pereira Filho, J.G., Sinderen, M.J. van Architectural Requirements for Building Context-Aware Services Platforms. Proceedings of the 9th Open European Summer School and IFIP Workshop on Next Generation Networks (EUNICE 2003) (2003, september 8 / 2003, september 10). (pp. 62-69)
- Eertink, H. , Kranenburg van, H., Hesselman, C.E.W. Context-aware Content Distribution and Adaption. Proceedings of the 6th International Symposium on Wireless Personal Multimedia Communications (2003). Yokosuka, Kanagawa, Japan
- Guizzardi-Silva Souza, R. , Aroyo, L.M., Wagner, G. Agent-oriented Knowledge Management in Learning Environments: A Peer-to-Peer Helpdesk Case Study. AAAI Technical Report SS-03-01 (2003, maart 24 / 2003, maart 26). (pp. 15-22) Stanford, California, USA ISBN: 1-57735-178-9
- Guizzardi-Silva Souza, R. , Aroyo, L.M., Wagner, G. Help&Learn: A Peer-to-Peer Architecture to Support Knowledge Management in Collaborative Learning Communities. Proceedings of XIV Brazilian Symposium on Computers in Education (2003). Rio de Janeiro
- Hesselman, C.E.W. , Eertink, E.H., Widya, I.A., Huizer, E. A Mobility-aware Broadcasting Infrastructure for a Wireless Internet with Hotspots. 1st ACM International Workshop on Wireless Mobile Applications and Services on WLAN Hotspots (2003, september 19 / 2003, september 19). (pp. 103-112) San Diego CA, USA ISBN: 1-58113-768-0
- Konstantas, D. , Herzog, R. Continuous monitoring of vital constants for mobile users: the MobiHealth approach. Proceedings of the 25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2003. 4, (2003, september 17 / 2003, september 21). (pp. 3728-3731) IEEE Engineering in Medicine and Biology Society ISBN: 0-7803-7789-3
- Meent, R. van de , Pras, A., Mandjes, M.R.H., Berg, J.L. van den, Nieuwenhuis, L.J.M. Traffic measurements for link dimensioning - a case study. Traffic measurements for link dimensioning - a case study Lecture notes in computer science nr: 2867, (2003). (pp. 106-117) ISSN: 0302-9743
- Widya, I.A. , Halteren, A.T. van, Jones, V.M., Bults, R.G.A., Konstantas, D., Vierhout, P.A.M., Peuscher, J. Telematic Requirements for a Mobile and Wireless Healthcare System derived from Enterprise Models. 7th International Conference on Telecommunications ConTEL 03EX652, (2003, juni 11 / 2003, juni 13). (pp. 527-534) ISBN: 953-184-052-0
- Zuidweg, M. , Pereira Filho, J.G., Sinderen, M.J. van Using P3P in a web services-base context-aware application platform. Proceedings of the 9th Open European Summer School and IFIP Workshop on Next Generation Networks (EUNICE 2003) (2003, september 8 / 2003, september 10). (pp. 238-243) ISBN: 963-421-576-9

## 2004

### *PhD-theses*

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#### *Books - chapter*

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#### 10. SWOT-analysis (excluding SWOT items already mentioned in part A)

##### *Strengths*

- Ability to attract external funding.
- Many and strong industrial contacts.
- Full embedding in CTIT Strategic Research Orientations A-SI and eHealth.

##### *Weaknesses*

- Inability to keep individual PhD student projects synchronized in time with collaborative research projects.
- Difficulty to timely adapt staffing levels according to work demand.

##### *Opportunities*

- Context-awareness (for 'smart' services) is a hot topic, which has many applications that are both challenging and relevant for society.
- Mobile e-health is a timely chosen application domain, as research will help solve problems related to the rising costs of healthcare.
- Services science is a new interdisciplinary field of study and research to which the group may contribute in the future.



**Title of the chair's research program:**

Formal Methods &amp; Tools (FMT)

**Subprogrammes or themes:** none**NABS code:** N07**Chairman:** prof.dr. E. Brinksma (until July 2005) / Dr. A. Rensink (from July 2005)**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal co-operations:** none**1. Mission statement**

The mission of the Formal Methods and Tools (FMT) chair is

**to study, develop and apply mathematical theories and methods for the design, modeling and analysis of functional and quantitative aspects of reactive systems, as well as to develop and apply supporting software tools.**

It builds on extended experience of the group in concurrency theory in general, and process algebraic and model checking approaches in particular, for the modelling of distributed, reactive systems, with applications in embedded and hybrid systems and complex software systems.

**2. Leadership**

The structure of the FMT group is flat and the mode of interaction is informal. Staff members have been relatively autonomous and free in their choice of research topic and approach, and in their activities to pursue national and international collaborations and to attract funding. Leadership has been by example rather than by direction. This loose structure, which relies heavily on the quality of the individual researchers, has been quite successful, as can be seen from the number of research projects awarded during the assessment period, as well as from the fact that two of the senior researchers, dr. H. Hermanns and dr. J.-P. Katoen, obtained professorial positions outside the university (in Saarbrücken and Aachen, respectively) in the course of 2003 and 2004.

Towards the end of the assessment period, from 1 July 2005 onwards, prof. H. Brinksma has accepted the position of scientific director of the Embedded Systems Institute in Eindhoven for 0.8 fte. Since then the daily leadership of the FMT group has been taken over by dr. A. Rensink, who at that time joined the group (coming from the neighbouring Software Engineering chair).

The current organisation of the group is centered around a one-hour weekly staff meeting, which includes one of the technicians and a postdoc researcher. At this meeting, current issues are discussed and actions are decided and assigned. A second weekly meeting is devoted to a scientific presentation by one of the group members or guest researchers. There is a general delegation of regular organisational and administrative tasks, regarding research, teaching, finance, housing and equipment, among the permanent staff. All other issues are taken up by the group leader and delegated on an ad hoc basis where necessary.

**3. Strategy and policy**

The FMT programme follows the philosophy that good formal methods research must be based on a balanced interaction between fundamental, tool-oriented, and application-oriented aspects. Fundamental research provides a sound theoretical foundation, tool-oriented research operationalizes and scales theoretical results up to application requirements, and application-oriented research is needed to validate both the theory and the tools, and provides feedback for their continual improvement. Only the combination of these aspects can lead to the development of useful and robust methods in the sense of well-understood procedures that can be applied by programmers and engineers to model, analyze and validate their designs.

### **3.a. Design in brief**

*In view of the above, the programme consists of three main areas of activity:*

#### **1. Extension of modelling and analysis methods**

This is the fundamental research part of the programme. It focusses on the extension of successful compositional approaches to the modelling and analysis of reactive systems to more expressive and powerful techniques. Particular areas of attention are: continuous behaviour (real-time and hybrid systems); probabilistic and stochastic behaviour (soft-real time systems, high-level performance modelling and analysis); partial-order semantics (event structures, McMillan prefixes); and software modelling (formalization of object-oriented paradigm, software dynamics). In each of these cases, there are the following aspects:

#### **2. Tool-oriented research**

Building tools is a very important step bridging pure theoretical research and practical applications. Although in an academic context we can hardly hope to build industrial-strength tools, still there are two levels of maturity that can be sought. First of all, there is the *proof-of-concept* tool, which serves as an affirmation that the theory or algorithm presented in a paper is feasible and has (in some sense) reasonable performance. Such a tool is not intended to be used by anyone except the authors. Secondly, one may recognize the level of *academic tool*, which, although also growing out of group research, has a longer lifespan, better support, incremental development, and, above all, actual users outside the group of developers.

The current tool-oriented research is organized around the following themes: model checking (model checking in the large, real-time model checking, guided-search model checking, software model checking); testing (model-based test generation and selection, coverage analysis); and quantitative analysis (integrated verification and performance analysis tools, hybrid analysis tools). Ongoing tool efforts in these areas that can be classified as *academic tools* in the above sense are: MoDeST and GROOVE for (software) model checking, TorX for testing, and Bhave for hybrid analysis.

#### **3. Application projects**

The ongoing application of formal methods and tools to industrial applications is part of the research programme. The chair is a firm believer in and practitioner of the industry-as-laboratory principle.

The FMT research programme is well-aligned with international developments in the field, where a general shift can be observed from purely theoretical research in formal methods to tool-oriented and application-oriented research. FMT focal points such as formal methods-based testing, (real-time) model checking, the integration of functional correctness and performance analysis, and the study of hybrid and embedded systems have gained prominence in the past period.

### **3.b. Programme development**

Below we describe plans and expected developments in the near and mid-term future.

The first and last of these items are consequences of the growing maturity of quantitative and stochastic techniques. This implies that tool development and application projects will start playing a more important role. The second and third items couple the study of quantitative and stochastic techniques to complementary issues of software modelling and verification.

An aspect not mentioned explicitly below, but inherent to all topics, is tool development. The chair is currently trying to systematise the development of "small" (academic) tools, so as to improve their lifespan and usability.

Sensor networks as application area.

Whether under the name “ambient intelligence”, “smart dust” or “ubiquitous computing”, it is clear that the area of sensor networks is one of the fastest growing and most promising emergent applications of computer science. At the same time, it is a young discipline, dominated by the drive to build things. The development of fundamental theory and formal methods is lagging behind. The FMT group has precisely the right mixture of expertise (quantitative methods including real-time and stochastic modelling, hybrid systems) to contribute at this juncture; the development research topics in this area together with the DACS group is one of the major planned new activities at the chair.

Modelling and programming with real-time obligations.

From the work in the group on software verification and real-time modelling we have observed that there is a need for a language that sits between the modelling and the programming level, and at the same time allows the proper specification of real-time obligations, not as an afterthought but as a first-class language feature. By positioning language between these levels (which may be thought of as embodied by Promela – the SPIN input language - on the one hand and Java on the other), one can do verification but also code generation/compilation on the basis of one and the same software artefact, thus meeting the goal of what is nowadays called *model-driven development*. By adding real time as a first-class feature, the resulting language is suitable for directly programming embedded systems.

Model extraction and static analysis for software verification.

One of the reasons why formal methods is still infrequently applied in the industrial practice is the lack of models on the right level of abstraction. (Note that this situation will continue to hold for the coming decades, despite the call for model-driven development already mentioned above, if only due to the continuing presence of legacy systems.) Another reason is the high level of expertise required for their usage. Both objections can be countered by developing *push-button*, *bottom-up* verification techniques. With push-button we mean that the application of a method is as straightforward (and essentially invisible) as type checking or compilation; with bottom-up we mean that the basis of the verification is not an external model but a model extracted from the code itself. These elements are combined in the area commonly known as *static analysis* or *abstract interpretation*. We plan to contribute to this area using graph transformation as an underlying formal technique, which has the combined advantage of offering close proximity to the software domain and a general framework for abstractions.

Methodological aspects of testing.

To some degree the formal theory of testing has reached a stable level. In order to transfer the insights gained over the years to the *practice* of testing, however, a better integration into current software development methodologies is still desirable. In particular, what is still imperfectly understood is the issue of *test selection*; i.e., among the infinite number of potential tests, how to select a feasible subset that has the highest chance of uncovering the most important errors. This is a problem that goes beyond the purely functional aspects of the systems under test, and requires probabilistic and stochastic methods for defining, measuring and optimizing towards coverage criteria. Preliminary work in this direction has started recently (after the assessment period) and is expected to yield applicable results in the near future.

#### 4. Processes in research, internal and external collaboration

As described above (Section 3) the leadership style has been to delegate responsibility for the research sub-programmes to the individual staff members. This means that there are smaller groups within the chair that meet regularly around a common theme, such as: model checking,

probabilistic modelling, testing, hybrid systems theory and (since recently) graph transformation. PhD students interact primarily with their direct supervisors and the other members of their sub-team. In addition, during the weekly lunch presentation, besides the regular 1-hour presentations, every 6 weeks there is a session where all those present briefly their current activities in the space of 5 minutes, with opportunity for the others to react.

Within every sub-theme there is a strong cooperation with other research groups, both within the faculty and (inter)nationally; for instance, locally with the DACS, DIES and SE groups of Computer Science, the MSCT group of Applied Mathematics, nationally with the Radboud university, the CWI and the university of Eindhoven, and internationally with groups in Aachen (Katoen); Aalborg (Larsen); Berlin (Taentzer, Ehrig); Bonn (Baier); Cordoba (D'Argenio), INRIA Rhône-Alpes (Garavel); Pasadena, California (Holtzmann); Saarbrücken (Hermanns); Santa Cruz, California (De Alfaro) - to name but a few.

Though this decentralised approach has resulted in high quality and output in several of the aforementioned areas, an inherent danger is a loss of focus. To counter this, recently an initiative has been started to create a better central overview of research plans and intentions, by listing them explicitly and going over the list on a regular basis. This, together with a more explicit statement of the chair's expectations in terms of research output (formulated in a so-called "research policy" document) should serve as a control on the cohesion of the group. Content-wise, measures to ensure cohesion have been discussed in section 3b.

## 5. Academic reputation (we mention highlights only, omitting PC membership etc)

### *Prizes and awards*

- Van der Bijl en Belinfante, winnaars STW-workshop "Oriëntatie op ondernemerschap"
- Van der Bijl en Belinfante, STW Valorisation grant fase 1, "Smartest, slimmer testen van software"

### *Editorships, memberships of scientific boards and others*

#### *Prof. dr. H. Brinksma:*

- Scientific Director ESI (2005-now)
- Member Gebiedsbestuur Exacte Wetenschappen NWO (2005-2006)
- Journal editor of:
  - IEEE Transactions on Software Engineering (2003);
  - Software Tools for Technology Transfer (2003-now);
- Steering committee member of:
  - TACAS (Tools and Algorithms for the Construction and Analysis of Systems, 2003-now);
  - FORTE (Formal Description Techniques for Networked and Distributed Systems) (2003);
- Strategic Management Board, ARTIST 2 IST Network of Excellence on Embedded Systems (2004-now)
- President Research Advisory Committee for Computer Science (BCI) of the Netherlands Organisation for Scientific Research (2003-2004)

#### *Prof. dr. H. Hermanns*

- Steering Committee member of
  - QEST (Quantitative Evaluation of SysTems, 2004-now)
  - ETAPS (European Joint Conference on Theory and Practice of Software, 2004-2005)
- Co-editor of
  - CAV (Computer Aided Verification, 2007)
  - CONCUR (Concurrency Theory, 2006)
  - TACAS (Tools and Algorithms for the Construction and Analysis of Systems, 2006)
  - FIT 2005 (Foundations of Interface Technologies)

*Prof. dr. ir. J.-P. Katoen*

- Member editorial board of Journal of Software, Academy Publishers (2006--now).
- Steering committee member of:
  - PROBMIV (Process Algebra and Performance Modelling, since 1999);
  - ETAPS (2002 and 2003, 2005--now);
  - QEST ((Quantitative Evaluation of SysTems, 2005--now)
- Guest editor of:
  - Journal of Software Tools and Technology Transfer (Springer, 2004);
  - Journal of Logic and Algebraic Programming (Elsevier, 2003);
  - Theoretical Computer Science (Elsevier, 2002).
- Editor/Organizer of:
  - GI/Dagstuhl seminar on Model-based testing (2002)
  - GI/Dagstuhl seminar on Validation of Stochastic Systems (2004)
  - QEST (Quantitative Evaluation of SysTems, 2004);
  - Workshop on 25 years process algebra (2005).

*Dr. ir. A. Rensink*

- Steering Committee member of
  - ECMDA-FA (European Conference on Model-Driven Architecture: Foundations and Applications, 2005-now)
- Proceedings editor of
  - ECMDA-FA (European Conference on Model-Driven Architecture: Foundations and Applications, 2006)
  - GT-VC (Graph Transformation for Verification and Concurrency, 2005, 2006 and 2007)
  - MDAFA (MDA: Foundations and Applications, 2003)
- Workshops chair of ECMDA-FA 2005 and 2007
- Guest editor of
  - TAOSD (Transactions on Aspect-Oriented Software Development, 2006)
- Best Tool Demonstration award, AGTIVE 2003, Charlottesville, Virginia, USA, October 2003

*Dr. M.I.A. Stoelinga*

- Organizer of
  - Nederlandse Testdag (2005)
  - IPA Lentedagen over Software Testen (2005)

**6. External validation*****6.a. Societal relevance***

The availability of methods to produce correct and reliable software systems is of great relevance for modern society. The ever increasing dependency on software system functionality and performance in all facets of modern society makes their correct, secure and reliable operation a critical factor. Formal methods and tools contribute to the development of dependable systems by developing methods and tools for their systematic design and analysis. The transfer of knowledge from the research within the group to industry is effected through the development of proof-of-concept and academic tooling and joint application projects; see above.

***6.b. Industrial contacts***

- ASML Eindhoven
- Philips Research Laboratory Eindhoven
- Bosch-Siemens
- CMG
- Ordina
- Embedded Systems Institute, Eindhoven
- Klasse Objecten, Soest
- National Aerospace Laboratory NLR

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Brinksma, prof.dr. H.	0,4	0,4	0,2
associate professor (uhd)	Hermanns, Prof.dr.-ing. H.	0,1	0,09	0,09
	Katoen, Prof.dr.ir. J.P.	0,4	0,4	0,22
	Rensink, Dr.ir. A.			0,2
assistant professor (ud)	Langerak, Dr.ir. R.	0,4	0,4	0,4
	Ruijs, dr.ir. T.C.	0,4	0,4	0,4
other junior staff (moz, twaio)	Belinfante, ir. A.F.E.	0,06	0,8	0,8
<b>Total tenured staff</b>		<b>1,77</b>	<b>2,49</b>	<b>2,3</b>
professor (hgl)	Brinksma, prof.dr. H.			0,04
	Larsen, Prof. K.G.	0,08	0,09	0,09
assistant professor (ud)	Stoelinga, M.I.A. dr.		0,17	0,4
postdoctoral fellows	Andova, S.	1,0	0,58	
	Argenio, dr. P.R. d'			0,84
	Daws, C.F.	1,0	0,91	
	Jansen, dr. D.N.			1,0
junior staff (aio, oio, moz-p)	Usenko, Y.S.	1,0	0,66	
	Bohnenkamp, H.C.	1,0	1,0	0,66
	Brandan Briones, L.	0,64	0,8	0,8
	Distefano, D.S.	0,46		
	Han, T.			0,13
	Kakumani, R.	0,18	0,4	0,22
	Kastenberg, ir. H.			0,4
	Kordy, P.T.			0,12
	Krilavicius, T.	0,8	0,8	0,8
	Kuijper, drs. W.			0,27
	Kurban, M.E.	0,63	0,8	0,8
	Khatti, M.		0,33	0,14
	Neuhausser, M.			0,13
	Turetayev, D.	0,8	0,6	
other junior staff (moz, twaio)	Zapreev, I.		0,64	0,8
	Bijl, ir. H.M. van der			0,4
	Boudali, H.			0,14
	Bujorianu, L.M.			0,14
	Klaren, Ir. J.	0,8	0,74	
	Sathyanathan, P.W.			0,4
<b>Total non-tenured staff</b>		<b>8,39</b>	<b>8,51</b>	<b>8,71</b>
<b>Total Research staff FMT</b>		<b>10,16</b>	<b>11,0</b>	<b>11,01</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

As described in Section 3, the research carried out in the group counts two groups of activities that need laboratory support to some degree: tools development and application-directed projects. The latter are typically carried out in close cooperation with the industrial partner in question, and the necessary laboratory infrastructure is borrowed from them. The former, on the other hand, involve group-internal software development. Especially for the category of *academic* tools (see section 3), there are two aspects that potentially need support: the physical system necessary for the development, including the development platform of choice, and the development process.



With regard to the former (the platform): the scope of the tool development efforts within the chair is such that the average off-the-shelf PC, possibly with memory extensions, suffices as a physical system; furthermore, we are in the happy situation that the IT support group of the faculty offers flexible support for non-standard experimental configurations.

With respect to the latter (the process): the FMT group has taken the lead within the faculty in initiating a shared software repository with facilities for versioning, reporting and collaboration. Although the problems involved in setting this up are more complex than initially expected, in the coming years we will continue devoting effort to this important part of the infrastructure.

### 8.b. FTE-funding PhDs/postdocs

Table 5

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	19%	5%	21%	15%
Research funds	67%	70%	69%	69%
Contracts	13%	24%	10%	16%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

<i>Name project</i>	<i>Start</i>	<i>End</i>	<i>Sponsor</i>
AMETIST: Advanced Methods for Timed Systems	1-4-2002	1-7-2005	European Commision
ARTIST: Advanced Real-Time Systems	1-4-2002	1-4-2006	European Commision
ARTIST-2: Network of Excellence on Embedded Systems Design	1-9-2004	1-9-2008	European Commision
HYCON: Hybrid Control -- Taming Heterogeneity and Complexity of Networked Embedded Systems	15-9-2004	15-9-2008	European Commision
ADHOC: Analysis and Design of Hybrid Systems using Optimal Control	24-7-2003	1-9-2007	NWO
AiSHA: Abstraction in Stochastic and Hybrid process Algebra	1-11-2005	1-11-2008	NWO
CASH: Compositional Analysis and Specification of Hybrid Systems	1-9-2001	31-1-2006	NWO
DARTS: Design and Analysis of Robust Timed Systems	15-9-2005	15-9-2009	NWO
GRASLAND: Graphs for Software Language Definitions	1-4-2005	31-3-2009	NWO
GROOVE: Graphs for Object-Oriented Verification	1-8-2004	1-10-2009	NWO
IMPASSE: Implementing McMillan Prefixes against State Space Explosion	15-3-2003	15-3-2007	NWO
MC=MC: Model-Checking of Infinite-State Markov Chains	15-3-2004	15-3-2008	NWO
MOCA: Modeling Control Aspects of Embedded Systems	1-5-2005	1-9-2009	NWO
MOQS: Modeling and Analysis of QoS of Component-Based Designs	1-11-2005	15-2-2009	NWO
QUPES: Verifying Quantitative Properties of Embedded Software	1-11-2005	1-11-2009	NWO
SPACE: Specification-based PerformAbility ChEcking	1-10-2000	1-10-2003	NWO
STRESS: Systematic Testing of Real-time Software Systems	15-3-2003	1-1-2008	NWO
Voss: Validation of Stochastic Systems	1-3-2001	1-3-2004	NWO
Voss-2: Validation of Stochastic Systems II	1-1-2005	1-1-2008	NWO
Verification of performance and dependability	1-10-2001	1-10-2006	NWO-VERN.IMPULS

<i>Name project</i>	<i>Start</i>	<i>End</i>	<i>Sponsor</i>
ESI/TANGRAM: Test Approach based on iNtegrated product Generation and product Realization applied to Asml Machines	1-3-2003	31-12-2005	SETER
ATOMYSTE: Atom splitting in embedded Systems testing	1-7-2005	1-4-2006	STW
Côte de Resyste: Conformance Testing for Reactive Systems	1-3-2000	28-2-2003	STW
HaaST: Verification of Hard and Softly Timed Systems	24-8-1999	1-12-2003	STW

## 9. Overview of the results

### 9.a. Description of scientific results

During the research assessment period we have seen a strengthening and consolidation of the research in quantitative and stochastic modelling and analysis techniques. This has resulted in a number of publications, of which we include several among the key publications (1, 2 and 3).

In the area of testing, attention is also slowly shifting from a pure functional point of view to, on the one hand, a more methodological embedding of the results, including optimization and strategies for selecting tests on the basis of their coverage (e.g., key publication 1) and on the other, including time in the tests (key publication 3).

In the area of model checking, research is continuing in how to tune existing model checking tools for specific purposes, such as optimal scheduling, thus demonstrating the use of general-purpose tooling rather than dedicated tools even in specialized application areas (key publication 4).

In the area of hybrid systems, the close cooperation with the MSCT group in applied mathematics is starting to pay off in the publication of results, one of which is included as key publication 5.

### 9.b. Key publications

<i>nr</i>	<i>Title</i>
1	Patricia Bouyer, Ed Brinksma, Kim Guldstrand Larsen: <i>Staying Alive as Cheaply as Possible</i> . In: R. Alur and G.J. Pappas (eds.), <i>HSCC 2004</i> , LNCS 2993, Springer Verlag, pages 203-218, 2004, ISSN: 0302-9743, ISBN: 3-540-21259-0
2	Christel Baier, Boudewijn R. Haverkort, Holger Hermanns, and Joost-Pieter Katoen. <i>Model-checking algorithms for continuous-time Markov chains</i> . IEEE Transactions on Software Engineering, 29(6):524-541, 2003, ISSN: 0098-5589
3	Laura Brandan Briones and Ed Brinksma. <i>A test generation framework for quiescent real-time systems</i> . In: <i>Formal Approaches to Software Testing, 4th International Workshop (FATES)</i> , LNCS 3395, Springer Verlag, pages 64-78, 2004, ISSN: 0302-9743, ISBN: 3-902457-01-5.
4	T. C. Ruys. <i>Optimal Scheduling Using Branch and Bound with SPIN 4.0</i> . Editors: Thomas Ball and Sriram K. Rajamani, <i>Model Checking Software, Proceedings of the 10th International SPIN Workshop</i> , LNCS 2648, Springer Verlag, pages 1 - 17, 2003, ISSN: 0302-9743, ISBN 3-540-40117-2.
5	R. Langerak and J. W. Polderman. <i>Tools for stability of switching linear systems: Gain automata and delay compensation</i> . In <i>Proc. 44th IEEE Conf. Decision and Control and Eur. Contr. Conf.</i> , Sevilla, Spain, 2005, pp. 4867-4872. IEEE Computer Society. ISBN: 0-7803-9567-0.

**9.c. Numerical overview of the results in a fixed format of categories***Table 8*

		2003	2004	2005
1 Academic publications	a. PhD-theses	1		
	b. in refereed journals	6	2	8
	c. international conference proceedings	14	18	24
	d. books			
	e. book -chapters		3	4
<b>Total</b>		21	23	36
2. International patents				

**9.d. Full outcome list****2003***PhD-theses*

Distefano, D.S. On model checking the dynamics of object-based software: a foundational approach. (2003, november 7). 313 pp. Enschede, The Netherlands Twente University Press Thesis advisor(s): prof.dr. H. Brinksma. ISBN: 90-365-1975-6

*Journal articles*

- Baier, C. , Haverkort, B.R.H.M., Hermanns, H., Katoen, J.P. Model checking algorithms for continuous-time Markov chains. IEEE transactions on software engineering nr: 6, 29, (2003). (pp. 524-541) ISSN: 0098-5589
- Brinksma, H. , Mader, A.H. Prozessalgebra, Teil 1. Automatisierungstechnik nr: 8, 51, (2003). 4 pp. ISSN: 0178-2312
- Brinksma, H. , Mader, A.H. Prozessalgebra, Teil 2. Automatisierungstechnik nr: 9, 51, (2003). 4 pp. ISSN: 0178-2312
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**10. SWOT-analysis (excluding SWOT items already mentioned in part A)***Strengths*

- Research quality and output, (inter)national reputation;
- Industry and international contacts;
- Mix of theoretical and tool/application-oriented approach;
- Combination of hybrid systems, quantitative analysis and software verification expertise.

*Weaknesses*

- Current relatively low number of "in-house" PhD students;
- Current dip in application-oriented projects;
- No current involvement in larger (integrated) European projects.

*Opportunities*

- New application areas (sensor networks);
- Growing awareness of dependability issues in industry;
- Involvement in CeDICT center of excellence;
- Involvement in LaQuSo branch at Twente;
- New professorial position.

*Threats*

- Understaffed for a period of time during 2004/2005;
- Deterioration in financial position due to low number of PhDs in assessment period.



**Title of the chair's program:**

Software Engineering (SE)

**Sub-programmes or themes:** none**NABS code:** N07**Chairman:** prof. dr. M. Aksit**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal co-operations:** none**1. Mission statement**

The Software Engineering group aims to contribute to the solution of the problems of stakeholders by developing and/or selecting optimal models along the software engineering process. A model is called optimal if it satisfies the constraints imposed by its context, i.e., the market, stakeholders, enabling technology, financial conditions, etc. These constraints are formulated in terms of quality factors, which therefore define the dimensions of the relevant characteristics of models. The following quality factors are explicitly addressed: correctness, composability, relevancy, evolvability, adaptability, reliability, acceptable time performance, traceability, cost reduce-ability. Our mission statement is

*'To model, implement and optimize software engineering processes for specifying, designing, implementing, verifying and optimizing software artifacts at various abstraction levels for the purpose of fulfilling the stakeholder's requirements of software systems'.*

**2. Leadership**

The group is managed by the senior research staff (Aksit, Van den Berg, Bergmans, Van den Broek, Rensink (until 7/2005) and Tekinerdogan). The non-technical management activities are shared among the staff members and partially by the PhD associates (such as organizing regular talks), while Aksit takes the responsibility of being the chair. The research activities of the group are informally divided under the following four complementary sub-groups: (a) Programming Languages level: Aspect-Oriented Software Composition (Bergmans), (b) Architecture level: Software Architectures (Tekinerdogan & Van den Berg), (c) Verification level: Design for Correctness (Rensink (until 7/2005) & Bergmans), and (d) Optimization level: Software Quality Optimization in case of Imperfect Knowledge (Van den Broek). General research objectives are managed by Mehmet Aksit, who is also actively involved in (almost) all research activities. The related projects are listed in Table 6. Since typical software development activity involves multiple of these levels, the staff members interact extensively by participating in common projects, jointly supervising PhD associates, joint publications and through informal channels. Examples of informal channels are for example, weekly presentations by the staff members, PHD associates and master students where all the staff members are expected to attend. Furthermore, submitted papers are generally reviewed by the staff members. Last but not least, since Aksit is involved in all research activities, he functions as the coordinator of the activities for more synergy and mutual fertilization.

**3. Strategy and policy****3.a. Design in brief**

The chair Software Engineering was formally established in the end of year 2000 by the appointment of Aksit as a full professor. Although there was a group of people working on various topics of software engineering under Aksit's informal leadership, this group did not have a formal status. Three of the staff members worked previously for a different chair (Aksit, Van den Berg and Van den Broek). Three new staff members were appointed for the Software Engineering Group (Bergmans, Rensink (appointed before the establishment of the chair) and Tekinerdogan).

Initially, the group had no externally financed projects (except the EasyComp project

supervised by Aksit). It was therefore absolutely necessary to acquire sufficient number of projects and recruit new PhD candidates. The faculty has helped the Software Engineering Group by allocating two first stream PhD associates (Nagy & Kurtev) and by financially compensating the "start-up deficit" of the group (will be realized at the end of 2006). The group has devoted a considerable amount of time for acquiring new projects which are listed in Table 6. This trend is still continuing. Consequently the number of PhD associates has grown considerably: 2 in 2001 up to 14 in 2005. This growth has provided sufficient financial support and research capacity to sustain the research activities. All these projects are integrated within the context of the CTIT institute.

Before joining the Software Engineering Group, the staff members have been working on various topics. It was necessary to harmonize the research interests of the staff members in a coherent and productive research framework. The staff members have shown great effort. For example, Van den Berg has started research activities in the domain of Model Driven Architecture and recently in evolvability and traceability of software architectures; Van den Broek has started carrying out research on soft computing techniques for software quality optimization and in evolvability and traceability of software architectures; Rensink has developed a new graph-based framework which provides an elegant formal background for several research activities in the group. Bergmans' and Tekinerdogan's PhD topics and research interests naturally enriched the research activities of the group. The success of recruiting new projects can be partially attributed to the success of the harmonization of research interests of the group members.

The Software Engineering Chair as much as possible aims to apply its research contributions to industrial cases. The group is the major contributor to the Embedded Systems Institute with three projects. Furthermore, the group continues its tradition of giving industrial courses (in average 7 courses in a year). Last but not least, the group is currently carrying out two large technology transfer projects to industry (ASML) for the purpose of exploiting its research contributions.

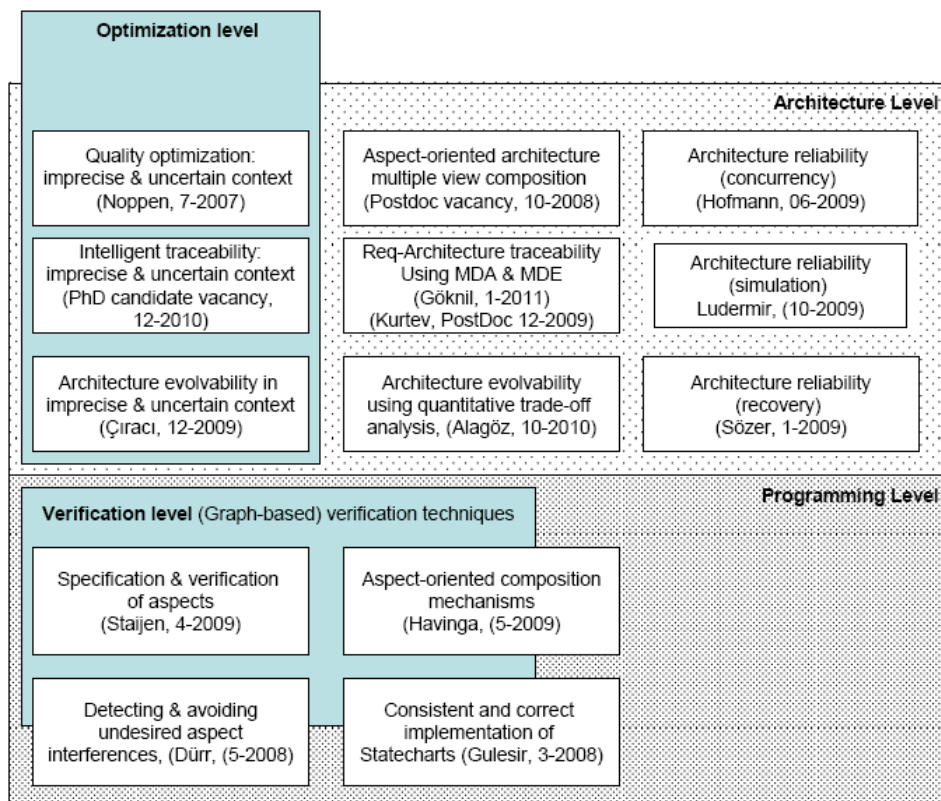
The research challenges of the Software Engineering group can be summarized under the four complementary topics. The first three topics refer to the levels programming languages, architecture and optimization levels, which are listed in the section Leadership. The verification level challenges, which are not explicitly shown in the following list form part of the programming-languages level challenges. The fourth topic refers to the challenges related to defining the relevant quality models, which are in fact shared by the first three levels. These challenges are related through (i) the shared quality models; and (ii) architecture design processes which integrate various facets of software development into a coherent methodological framework.

1. Programming languages level: To define and implement expressive and intuitive language constructs for modularization and run-time behaviour of software so that adaptability and evolvability of software systems are enhanced and complexity of software systems are reduced, while enabling reasoning about its correctness.
2. Architecture-level:
  - a. To define effective and intuitive problem analysis, solution synthesis and restructuring processes for transferring stakeholder's requirements into software architectures so that the desired quality factors can be fulfilled effectively.
  - b. To define expressive, scaleable and reusable model transformation techniques to cope with (non-structure preserving) evolutions, to enable traceability and to enhance portability.
3. Optimization-level: To define expressive models for processes and products at different levels of abstractions and to specify effective and scaleable optimization algorithms over these models with respect to the quality constraints in the presence of imperfect information (uncertainty and impreciseness).

4. Quality-related: To define expressive and scaleable (software engineering) models for the software qualities cost reduction, correctness, performance, evolvability, reliability, traceability, portability and adaptability so that these models can be used to evaluate the quality of models at different levels of abstraction; to carry out quality trade-off analysis and to direct design processes accordingly.

### 3.b. Programme development

The following figure depicts the current research activities at four complementary levels. The names in the parentheses correspond to the temporary research members financed by external projects and the dates indicate the contract period. The researchers are appointed as PhD candidates unless specified otherwise. As shown in the figure, optimization and graph-based verification activities are partially overlapping with the architecture and programming level activities. It is likely that more research projects adopt these techniques in due time. Furthermore, there are formal and informal links among the research activities due to the mutual involvement of the staff members in the projects. The research activities that are carried out in cooperation with the Embedded Systems Institute (ESI) are shown as rectangles with double border lines and classified under the CTIT SRO UBRICKS programme. These projects study the problems that are specific to embedded system design (Software for TV, MRI Scanners and Lithography scanners). The remaining research activities are more general in nature and are classified under the SRO A-SI. Since the group has currently reached its full research capacity with the necessary number of PhD candidates and postdocs, it is expected that the research output of the group will reach its optimal level at the end of 2007. Since the group has been successful in recruiting new projects, we expect that the research output will be sustained in the future.



#### 4. Processes in research, internal and external collaboration

The research in the group is split into subtopics, integrated through the common theme of Quality-Oriented Software Engineering. In general, each staff member is responsible for his own research area, including acquisition, strategy, research, and daily supervision of PhD candidates, post-docs and M.Sc. students. The chair of the group is involved in all these activities, both organizational, strategic and content-wise; as a result he can co-ordinate interactions among different activities within the group. Collaborations among the people working on different subtopics occurs naturally since the work within subtopics tends to show certain overlapping subareas, such as aspect-oriented software development, software development processes, traceability, verification, etc. Further forums for interaction are the weekly staff meetings for organizational matters and the weekly TRESE Technical Talks, which serves as a forum for presenting and discussing the performed research among all persons within the software engineering chair.

Outside collaborations are generally the result of active participation in projects and events; for example the participation in projects with the Embedded Systems Institute has led to several follow-ups, involving many people within the group. Also the participation (by many group members) within the Network of Excellence on AOSD is an important form of external collaboration, and a source for new collaborations.

#### 5. Academic reputation (we mention highlights only, omitting PC membership etc)

*Prof dr ir Mehmet Akşit*

- Keynote and invited talks at the conferences
  - "Challenges in Applying the Concept of Model Driven Architecture", OMG Information Days, Amsterdam, February 18, 2003
  - "7 Concepts for Creating Living Software", UYMK (First National Conference on Software Engineering), Izmir, October 23, 2003
  - "Principles of Aspect-Oriented Programming Languages, Design Dimensions and the Composition Filters Approach", Invited talk at Langages et modèles à objets, March 17, 2004. Lille.
  - "Design Language Trade-Offs", Software Engineering Properties and Aspect Technologies Workshop, at AOSD'2005 Conference, Chicago, March 15, 2005
  - "Challenges in Designing High-Quality Software Systems", Biltek (Informatics Technology Conference), Eskisehir, June 10, 2005.
  - "Aspect-oriented modeling the past, present and the future: The Compose\* experience", UYMK (Second National Conference on Software Engineering), Ankara, September 24, 2005
- Program Chair of AOSD (ACM Conference Aspect-Oriented Software Development) 2003
- Founding Member of International Foundation on Aspect-Oriented Software Development
- Voting Member of the European Foundation on Object-Oriented Systems (AITO)
- Editor-in-Chief of Transactions on Aspect-oriented Software Development (Springer Verlag)
- Co-editor of the special journal issue: Computational Intelligence in Software Engineering, Journal of Fuzzy Sets and Systems, 2004.
- 'Expert' role at Student Extravaganza of AOSD 2003

*Dr ir Arend Rensink (until July 2005)*

- Steering Committee member of ECMDA (European Conference on Model-Driven Architecture)
- Conference chair/co-organiser/editor of
  - ECMDA-FA 2006 (European Conference on Model-Driven Architecture: Foundations and Applications)
  - GT-VC 2005, 2006 and 2007 (Graph Transformation for Verification and Concurrency)
  - MDFA 2003 (MDA: Foundations and Applications)
- Guest editor of
  - TAOSD (Transactions on Aspect-Oriented Software Development), special issue on Dependencies and Interactions with Aspects

*Dr ir Lodewijk Bergmans*

- Doctoral Symposium Chair ECOOP 2003 (European Conference on Object-Oriented Programming)
- Workshop Chair of AOSD 2002 (Aspect-Oriented Software Development Conference)
- 'Expert' role at Student Extravaganza of AOSD 2005

*Dr ir Bedir Tekinerdogan*

- Steering Committee member of Early Aspects: Aspect-Oriented Requirements Engineering and Architecture Design Workshops (2005-..).
- Conference chair of TSAD 2006 (UYMK 2006), First Turkish Software Architecture Design Conference, Istanbul, November, 2006.
- Editor of IEE Proceedings Software. Special Issue of Early Aspects: Aspect-Oriented Requirements Engineering and Architecture Design, 2003.

**6. External validation*****6.a. Societal relevance***

The group adopts for more than a decade an industry-as-laboratory approach in which research problems are grounded in practical problems. The research ideas are refined through the medium of continual and incremental case studies. This approach is clearly visible in the projects that the group is carrying out. The gross of these projects are externally funded and in close cooperation with the industry. For example, the IDEALS project aims at developing a software design methodology that realizes the structured composition of software from separate modules, while handling system-wide interacting aspects of a problem domain. The results of the project are essential for the engineering of next generation complex embedded systems. In this project, Twente University, Eindhoven University of Technology, CWI and ASML co-operate with the Embedded Systems Institute. The TRADER project aims to develop methods and tools for ensuring reliability of consumer electronic products. This should result in minimizing product failures that are exposed to the user. Within this project we are in close cooperation with Philips Semiconductors and Embedded Systems Institute. The DARWIN project aims to develop methods and tools for optimizing system evolvability. This should result in a faster time to market for product iterations whilst maximizing technology reuse. Hereby we focus on the industrial sector of medical imaging, in particular that of MRI scanners. The QuadREAD project aims to improve the integration of requirements engineering and architectural design. The better alignment of these two disciplines will reduce maintenance cost in evolving software systems.

***6.b. Industrial contacts***

- ASML
- Embedded Systems Institute
- Philips Research
- Philips Semiconductors
- Philips TASS
- Siemens Aktiengesellschaft (Siemens)
- IBM United Kingdom Limited (IBM UK)
- Belastingdienst apeldoorn.
- Logica CMG (Amstelveen)
- Da Capo AI Fine
- AVV Rikswaterstaat Rotterdam
- Cybersoft (Turkey, Ankara/Istanbul)
- Aselsan (Turkey, Ankara)
- Milsoft (Turkey, Ankara)
- LBS (Turkey, Istanbul)
- Beko (Turkey, Izmir)
- Cap gemini Utrecht

- Microsoft Redmond
- Ordina
- Rohill Technologies Nederland
- Thales Hengelo
- 3T
- AMB-IT
- HOLOS
- SAP AG,
- Inspectie Verkeer en Waterstaat
- Chess Information Technology
- Getronics PinkRoccade

## 7. Researchers and other personnel (“wp”)

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Aksit, Prof.dr.ir. M.	0,4	0,4	0,4
associate professor (uhd)	Rensink, Dr.ir. A.	0,4	0,4	0,2
assistant professor (ud)	Berg, Dr.ir. K.G. van den	0,4	0,4	0,4
	Bergmans, Dr.ir. L.M.J.	0,4	0,4	0,4
	Broek, Dr. P.M. van den	0,4	0,4	0,4
	Tekinerdogan, Dr.ir. B.		0,2	0,4
<b>Total tenured staff</b>		<b>2,0</b>	<b>2,2</b>	<b>2,2</b>
assistant professor (ud)	Tekinerdogan, Dr.ir. B.	0,2	0,2	
postdoctoral fellows	Sathyanathan, P.W.			0,29
junior staff (aio, oio, moz-p)	Bijl, ir. H.M. van der	1,0	1,0	0,49
	Ciraci, S.			0,07
	Durr, ir. P.E.A.		0,5	0,8
	Glandrup, Ir. M.H.J.	1,0	0,6	0,14
	Gomes Ludermit, P.			0,13
	Gulesir, G.		0,64	0,8
	Havinga, ir. W.K.			0,44
	Hofmann, C.			0,47
	Ivanov, M.sc. I.K.	0,8	0,8	0,4
	Kastenbergh, ir. H.		0,33	0,39
	Krechetov, I.			0,2
	Nagy, I.	0,8	0,8	0,8
	Noppen, ir. J.A.R.	0,8	0,8	0,8
	Sözer, H.			0,73
	Staijen, ir. T.			0,54
other junior staff (moz, twaio)	Byelas, H.		0,06	0,54
	Kleppe, drs. A.G.			0,11
<b>Total non-tenured staff</b>		<b>4,6</b>	<b>5,73</b>	<b>8,14</b>
<b>Total Research staff SE</b>		<b>6,6</b>	<b>7,93</b>	<b>10,34</b>



## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

### 8.b. FTE-funding PhDs/postdocs

Table 5

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	45%	40%	13%	33%
Research funds	32%	39%	33%	34%
Contracts	23%	21%	54%	33%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

<i>Name project</i>	<i>Start</i>	<i>End</i>	<i>Sponsor</i>
AOSD-EUROPE: European Network of Excellence on Aspect-Oriented Software Deve	1-9-2004	1-9-2008	European Commision
EASYCOMP: Easy Composition in Future Generation Component Systems	1-6-2000	1-6-2003	European Commision
AOSAD: Aspect-Oriented Software Architecture Design	1-7-2003	1-6-2009	NWO
CEDUF: Dealing with Conflicting and Evolving Designs Using Fuzzy Logic	1-7-2003	1-7-2007	NWO
GRASLAND: Graphs for Software Language Definitions	1-4-2005	31-3-2009	NWO
GROOVE: Graphs for Object-Oriented Verification	1-8-2004	1-10-2009	NWO
ESI/IDEALS: Idiom Design for Embedded Applications on Large Scale	1-3-2003	1-3-2007	SENER
ESI/DARWIN: Designing Highly Evolvable System Architectures	1-10-2005	1-10-2009	SENER / BSIK
ESI/TRADER: Television Related Architecture and Design to Enhance Reliability	1-8-2004	1-8-2008	SENER / BSIK
ATOMYSTE: Atom splitting in embedded Systems testing	1-4-2002	1-7-2005	STW

## 9. Overview of the results

### 9.a. Description of scientific results

Programming level: Since begin 90's the group has pioneered aspect-oriented language concepts through the programming languages Sina and Composition Filters. Our research contribution has been the extension of the Composition Filters model with a declarative specification language for defining constraints upon the possible compositions of aspects at a shared join point, and by using an extended notion of join points.

Architecture level: We have developed an organization of the Meta Object Facility (MOF) meta-modeling architecture based on a simple and uniform representation of all model elements no matter at which level they are defined, and have presented a transformation language based on this framework which is independent of the instantiation and generalization mechanism specific for a given model

Verification level: We have developed an approach and tool for state space generation on the basis of graph transformation rules, and applied it to a number of scenario's to define semantics and verify correctness, including for instance model transformation (a semantics for one of the QVT language submissions) and software behaviour (a semantics for an object-oriented language).

Optimization level: Since end 90's, the group has pioneered the application of fuzzy-probabilistic techniques for modeling software design processes. We have reduced the quantization error and contextual bias problems of software development methods by transforming heuristic rules into fuzzy logic-based methodological rules. Furthermore, we have developed an enhancement of current software development methods based on Markov Decision Theory, which determines the estimated optimal development schedule with respect to probabilistic product demands and resource constraints, developed a supporting tool, and applied to an industrial case.

### 9.b. Key publications

Table 7

nr	Title
1	Francesco Marcelloni and Mehmet Aksit, Fuzzy logic-based object-oriented methods to reduce quantization error and contextual bias problems in software development, Fuzzy Sets and Systems 145, pp. 57-80 (2004)
2	Arend Rensink, Representing First-Order Logic using Graphs, International Conference on Graph Transformations (ICGT), H. Ehrig and G. Engels and F. Parisi-Presicce and G. Rozenberg (Eds), LNCS 3256, Springer-Verlag, 2004, pp 319-335
3	Ivan Kurtev and Klaas van den Berg, A Language for Model Transformations in the MOF Meta-modeling Architecture, Proceedings of Model-Driven Architecture: Foundations and Applications 2004, Uwe Assman (ed.), pp. 29-46 (2004)
4	Istvan Nagy, Lodewijk Bergmans and Mehmet Aksit, Composing Aspects at Shared Join Points, Proceedings of International Conference NetObjectDays, NODe2005, Lecture Notes in Informatics P-69, pp 1-16, (2005)
5	Joost Noppen, Mehmet Aksit, Victor Nicola and Bedir Tekinerdogan, A market-driven approach based on Markov decision theory for optimal use of resources in software development, IEE Proceedings - Software 155, pp 85-94 (2004)

### 9.c. Numerical overview of the results in a fixed format of categories

Table 8

		2003	2004	2005
1 Academic publications	a. PhD-theses			1
	b. in refereed journals		5	
	c. international conference proceedings	10	18	21
	d. books	1		
	e. book -chapters	1	2	1
<b>Total</b>		12	25	23
2. International patents				

### 9.d. Full outcome list

#### 2003

##### Conference proceedings

Aksit, M. Dynamic adaptive and reconfigurable systems: survey and prospective vision. Paper Workshop on Distributed Auto-adaptive Reconfigurable Systems (DARES) - International Conference on Distributed Computing Systems (ICDCS), 2003 (2003, mei 19 / 2003, mei 22). 6 pp. Providence, Rhode Island IEEE

Aksit, M. Proceedings of the 2nd International Conference on Aspect-Oriented Software Development 2003. Proceedings of the 2nd International Conference on Aspect-Oriented

- Software Development 2003 (2003). 198 pp. Boston, USA ACM Press ISBN: 1-58113-660-9 (Editor(s))
- Broek, P.M. van den Comparison of two approaches to approximate reasoning. Proceedings of the Third Conference of the European Society for Fuzzy Logic and Technology (2003, september 10 / 2003, september 12). (pp. 512-516) Zittau, Germany European Society for Fuzzy Logic and Technology (EUSFLAT) ISBN: 3-9808089-4-7
- Kurtev, I. , Berg, K.G. van den Model Driven Architecture based XML Processing. Proceedings of the 2003 ACM Symposium on Document Engineering (2003). (pp. 246-248) New York, USA ACM ISBN: 1-58113-724-9
- Kurtev, I. , Berg, K.G. van den, Aksit, M. UML to XML-Schema Transformation: a Case Study in Managing Alternative Model Transformations in MDA. Proceedings of Forum on Specification and Design Languages FDL2003 (nr: 1636-9874), (2003). 12 pp. Frankfurt, Germany ECSI
- Nagy, I. , Bergmans, L.M.J., Aksit, M. Composition Graphs: a Foundation for Reasoning about Aspect-Oriented Composition. FOAL 2003 Proceedings-Foundations of Aspect-Oriented Languages (nr: TR-03-05), (2003). (pp. 1-9) Iowa State University, USA
- Rensink, A. Towards Model Checking Graph Grammars. Technical Report DSSE-TR-2003-2: Proceedings of the 3rd Workshop on Automated Verification of Critical Systems (nr: TR-2003-2), (2003, april 2 / 2003, april 3). (pp. 150-160) Southampton, UK University of Southampton
- Tekinerdogan, B. ASAAM: Aspectual Software Architecture Analysis Method. Proceedings of Aspect-Oriented Requirements Engineering and Architecture Design Workshop (2003, maart 17 / 2003, maart 17). 8 pp. Boston, USA
- Tekinerdogan, B. Formalizing Agile Software Development Methods. Proceedings of Impact of Software Process on Quality Workshop (2003, juni 6 / 2003, juni 6). 8 pp. Ankara, Turkey
- Tekinerdogan, B. , Aksit, M. Managing Variability in Product Line Scoping using Design Space Models. Proceedings of Workshop Software Variability Management (2003, februari 13 / 2003, februari 14). (pp. 5-12) Groningen, the Netherlands Rijksuniversiteit Groningen

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- Aksit, M. , Menzini, M., Unland, R. Objects, Components, Architectures, Services and Applications for a Networked World. LNCS nr: 0302-9743, (2003). 430 pp. Berlin, Germany Springer-Verlag ISBN: 3-540-00737-7 (Editor(s))

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- Tekinerdogan, B. , Aksit, M. Fuzzy Evaluation of Domain Knowledge. Studiess in Fuziness: Software Engineering with Fuzzy Theory (2003). 10 pp. Berlin Springer-Verlag ISBN: 3-540-00472-6

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- Aksit, M. The 7 C's for Creating Living Software; A Research Perspective for Quality Oriented Software Engineering.. Turkish journal of electrical engineering and computer sciences nr: 2, 12, (2004). (pp. 61-95) ISSN: 1300-0632
- Broek, P.M. van den , Noppen, J.A.R. Comparison of two approaches to dynamic programming. Sigact news 34, (2004). (pp. 111-116) ISSN: 0163-5700
- Marcelloni, F. , Aksit, M. Fuzzy Logic-Based Object-Oriented Methods to Reduce Quantization Error and Contextual Base Problems in Software Development. Fuzzy sets and systems nr: 145, (2004). (pp. 57-80) ISSN: 0165-0114
- Noppen, J.A.R. , Aksit, M., Nicola, V.F., Tekinerdogan, B. Market-Driven Approach Based on Markov Decision Theory for Optimal Use of Resources in Software Development. IEE proceedings- software nr: 2, 151, (2004). (pp. 85-94) ISSN: 1462-5970

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- Bijl, H.M. van der , Rensink, A., Tretmans, G.J. Compositional based testing with ioco. Formal approaches to software testing Lecture notes in computer science 2931 (nr: VIII), (2003, oktober 6). (pp. 86-100) Berlin Springer ISBN: 3-540-20894-1 / ISSN: 0302-9743
- Broek, P.M. van den , Noppen, J.A.R. Approximate Reasoning with Fuzzy Booleans. UPMU 2004, 10th international conference on information processing and management of uncertainty in knowledge based systems 2, (2004). (pp. 1429-1434) Italie editrice universita la sapienza ISBN: 88-87242-54-2
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- Jones, V.M. , Rensink, A., Ruijs, T.C., Brinksma, H., Halteren, A.T. van A formal MDA approach for mobile health systems. Second European workshop on model driven architecture (MDA) (nr: 17-04), (2004, september 7 / 2004, september 8). (pp. 28-35) Canterbury, UK University of Kent, Computing laboratory
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- Nagy, I. , Bergmans, L.M.J. Towards Semantic Composition in Aspect Oriented Programming. 1st european interactive workshop on aspects in software (2004).
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- Tekinerdogan, B. , Bilir, S., Abatlevi, C. Integrating Platform Selection Rules in the Model Driven Architecture Approach. Proceedings of Model-Driven Architecture: Foundations and Applications (2004, juni 10 / 2004, juni 11). (pp. 186-203)

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ISBN: 0-32-121796-7

Marcelloni, F. , Aksit, M. Automating Software Development Process using Fuzzy Logic. Soft Computing in Software Engineering Series: Studies in Fuzziness and Soft Computing software engineering series nr: 159, (2004). (pp. 97-124) New York springer verlag  
ISBN: 3-540-22030-5

#### **2005**

#### *PhD-theses*

Kurtev, I. Adaptability of Model Transformations. (2005, mei 19). Enschede Universiteit Twente  
Thesis advisor(s): Prof.dr.ir. M. Aksit, Dr.ir. K.G. van den Berg.

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Bakker, J.P. , Tekinerdogan, B., Aksit, M. Comparative Analysis of Early Aspect Approaches. in Workshop Proceedings: Early Aspects: Aspect-Oriented Requirments Engineering and Architecture Design Workshop (2005).

Berg, K.G. van den , Conejero, J.M. A Conceptual Formalization of Crosscutting in AOSD. Technical Report TR/25-05 (2005). (pp. 46-52) University of Extremadura  
ISBN: 84-7723-670-4

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Durr, P.E.A. , Staijen, T., Bergmans, L.M.J., Aksit, M. Reasoning About Semantic Conflicts Between Aspects. EIWAS 2005: 2nd European Interactive Workshop on Aspects in Software (2005).

Gomes Ludermit, P. , Guizzardi-Silva Souza, R., Sona, D. Dr. Finding the right answer: an information retrieval approach supporting knowledge sharing. Proceedings of the AAMAS Agent Mediated Knowledge Management Workshop (2005, juli 25). (pp. 27-40) New York, USA ACM ISBN: 1-59593-094-9

Gulesir, G. , Bergmans, L.M.J., Durr, P.E.A., Nagy, I. Separating and Managing Dependent Concerns. LATE: Linking Aspect Technology and Evolution Workshop (2005).

Hofmann, C. Flexible Call-by-call Settlement-An Opportunity for Dynamic AOP. Proceedings of the Second Synamic Aspects Workshop (2005). (pp. 19-26)

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Kurtev, I. , Berg, K.G. van den Building Adaptable and Reusable XML Applications with Model Transformations. 14th International World Wide Web Conference (WWW2005) (2005). (pp. 160-169) ACM Press ISBN: 1-59593-052-3

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- Tekinerdogan, B. , Bilir, S., Abatlevi, C. Integrating Platform Selection Rules in the Model Driven Architecture Approach. Computer Science Lecture notes in computer science 3599, (2005). (pp. 159) Springer Verlag GmbH ISSN: 0302-9743
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#### *Books - chapter*

- Kurtev, I. , Berg, K.G. van den MISTRAL: A Language for Model Transformations in the MOF Meta-modeling Architecture. Model Driven Architecture: European MDA Workshops: Foundations and Applications Lecture Notes in Computer Science, (2005). 20 pp. Springer Verlag GmbH ISBN: 3-540-28240-8

### **10. SWOT-analysis (excluding SWOT items already mentioned in part A)**

#### *Strengths*

- Harmonious group with a vision and well-defined objectives.
- Ability to attract external funding.
- Has been at the centre of the object, aspect, and architecture research community.
- Has strong collaboration with industry (through Embedded Systems Institute) and the Ministry of Traffic Management and Tax office.

#### *Opportunities*

- The group has pioneered aspect-oriented techniques and there is an increasing demand for aspect-orientation.
- The group has pioneered synthesis-based (domain-driven) software architecture design and there is an increased demand for these techniques.
- The group has pioneered soft computing and software engineering techniques and there is an increasing demand for these.
- The group has developed several tools which have been adopted by industry. This should create industrial research projects.

**Part III Properties Cluster**

An ICT system that satisfies its functional requirements is fit for purpose only if it also satisfies a number of additional properties. We present the research of the three Computer Science groups that focus on properties:

7. The CAES group focuses on energy efficiency properties.
8. The DACS group focuses on dependability properties.
9. The DIES group focuses on security properties





**Title of the chair's program:**

Computer Architectures for Embedded Systems (CAES)

**Subprogrammes or themes:** energy-efficient dependable architectures for embedded systems**NABS code:** N07**Chairman:** prof. dr. ir. Th. Krol**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal cooperations:** CTIT, MESA+, NIRICT**1. Mission statement**

A networked embedded system is a mixture of hardware and software: it may be as simple as a sensor, or as complex as a portable device, or even an entire car or building. Such systems are increasingly based upon a wirelessly connected network of scalable and customisable System-on-Chip devices. For networked embedded systems, cooperation is a necessity, to perform their tasks with sufficient quality or efficiency, and to reach the required functionality. These systems should therefore be open, scalable and dependable, integrating heterogeneous devices ranging from tiny actuators to large computers. Our mission is:

*'to perform research on energy-efficient dependable architectures for networked embedded systems, by combining computer architectures, systems software, networking, and tools'.*

**2. Leadership**

During the reporting period a full professor headed the group and was responsible for the research strategy, research program and educational activities of the group. The research itself is mainly carried out by the PhD students, funded by STW/Progress, NWO, BSIK, EU-IST projects and industry. Every student has a daily supervisor from the permanent staff possibly assisted by a PostDoc. Where possible MSc students carry out research as part of a PhD project or do an independent smaller assignment in cooperation with industry.

The open and informal atmosphere of the group (staff members and PhD students) invites to working together, promotes cross-discipline research and attracts MSc students. This is also one of the reasons why we have quite a number of Dutch PhD students in our group.

In the reporting period CAES has been very successful in project acquisition. Part of this success can be explained by the open attitude we have towards cooperation with other groups inside of the UT (e.g. DIES, ICD, SAS, DMMP) and outside of the UT.

**3. Strategy and policy****3.a. Design in brief**

The research in this area is centred on the design and implementation of efficient architectures for dependable networked embedded systems. The key research challenges are:

- to master the *growing complexity* of networked embedded systems,
- to *reduce* the development costs and time to market,
- to foster *dependability* (i.e. availability, reliability, integrity and maintainability) as embedded systems are business or safety critical in almost every human endeavour,
- to improve *scalability* as the number of networked embedded devices can become enormous, and cooperation between these devices is essential in order to achieve the required quality and functionality,
- to minimize *resource usage* (e.g. energy consumption, memory, communication bandwidth) because these costs are a limiting factor for the widespread use and usability of embedded systems,

- to support the *dynamics* of systems and environments to achieve optimal efficiency, quality and functionality.

### ***3.b. Programme development***

As stated above the main emphasis of the group is on efficient architectures for dependable networked embedded systems. Within this theme the chair performs research on three related key areas:

- 1) efficient architectures for streaming applications,
- 2) wireless networked embedded systems and
- 3) dependability issues of networked embedded systems.

Energy-efficiency and dependability are the main drivers of our research. Energy-efficiency is important for streaming applications found in battery powered mobile devices (e.g. PDAs and portable multimedia players), and is of crucial importance for wireless sensor networks. Dependability plays an important role in sensor networks (nodes may fail or run out of energy unexpectedly), but due to the abundance of nodes distributed applications continue despite of failing nodes. In MPSoC (Multi Processor Systems-on-Chip) systems for streaming applications dependability techniques also play an important role. One of the problems in manufacturing a MPSoC with millions of transistors using deep-submicron technologies (90 nm and below), is an increase in the probability of defects in silicon, which results in decreasing manufacturing yield. To effectively deal with this increased defect density, we need efficient methods for fault detection, localization, and fault tolerant architectures implemented on-chip.

#### *Efficient Architectures for Streaming Applications*

Whereas computer architects for desktop systems only recently are slowly moving towards multi-core processors, the research on MPSoC architectures for networked embedded systems already started much earlier in our group because of energy-efficiency reasons. Our research on energy-efficient systems for mobile (handheld) systems started in 1995 (EU project Moby Dick), but got a boost in the reporting period with the STW/Progress project Chameleon (2000-2005) and the NWO Gecko (2002-2006) project. In these projects we studied efficient reconfigurable MPSoC architectures. These projects proved to be very successful. The results of these projects are currently brought to the market via the spin-off company Recore Systems B.V.. The Chameleon and Gecko projects laid the foundation for new project proposals e.g. AWGN (Adaptive Wireless Networking) and AAF (Adaptive Ad-hoc Freeband) on cognitive radio, the EU-FP6 project 4S (Smart Chips for Smart Surroundings) and industry participation.

In the 4S project we designed the reconfigurable fabric for the MPSoC (Tile Processors, NoC and Network Interface). In this project we started to work on run-time mapping of tasks to processors in a MPSoC. Mapping tasks to processors is usually done at design-time, but we propose to perform this task at run-time. From an energy-efficiency point of view this research direction is quite promising but also very challenging. In 2005 a PhD project was started in this direction, and further external funding is expected.

Recently we got a number of requests from industry, whether our tiled MPSoC architecture, originally developed for mobile systems, also can be applied for efficient high-performance streaming applications. In 2005 we started with a project together with (and funded by) Philips Research on modelling of streaming applications. In 2006 this direction continued with research on memory structures for streaming applications and Network on Chip solutions for streaming media also funded by Philips Research/NXP. As part of a research cooperation with Thales Hengelo and Philips Medical Systems Best two (Philips/Thales funded) PhD students will start working on MPSoC architectures for streaming applications for phased array radar systems and medical image processing. It is expected that more research will be funded in this direction.

*Wireless Networked Embedded Systems (Wireless Sensor Nodes)*

In the reporting period the group started research on wireless sensor nodes; a new paradigm for bringing the flexibility of information technology in contact with almost all aspects of daily life. It foresees that people will be surrounded by deeply embedded and flexibly networked systems that provide easily accessible yet unobtrusive support for an open-ended range of activities, e.g. for safety and/or to increase productivity at work. These systems will be quite different compared to current computer systems, as they will be based on an abundant set of hardware artifacts and software entities, embedded in everyday objects or realized as new types of devices.

In this research we investigate new distributed mechanisms for networking and distributed collaboration, and evaluate their feasibility through experimentation. These mechanisms operate in a challenging environment of self-organizing collaborative networked embedded systems where nodes move, fail, and energy is a scarce resource. The main thrust of the work is therefore towards the development of new distributed systems support, and the development of efficient embedded networking, taking the specific features of sensor networks into account. In particular, schemes, which are able to work efficiently and dependably, in the presence of limited energy, processing power and memory, are developed.

This work is being performed in several national and international projects. The area started in 2000, in which year we initiated and coordinated the IST-EU project EYES, on energy efficient sensor networks. This was the first large project in Europe focusing on wireless sensor networks, and has been highly successful. Apart from the knowledge gained by the involved partners, several products have appeared on the market, based on the technologies developed in EYES. Also the UT spin-off company Ambient Systems B.V. can be considered as based on the research from that project. Projects initiated by our group include the STW/PROGRESS project Featherlight distributed systems on distributed system support for collaborating tiny devices, and the NWO project Consensus on algorithms and protocols for collaborative sensor networks. The Bsik project Smart Surroundings, initiated and coordinated by our group, is a large (13MEuro) national project on ubiquitous computing. We also participate in the EU-FP6 projects Cobis on collaborative business items, Aware on autonomous flying objects interacting with sensor networks, Embedded Wisents research and education roadmap, and e-Sense on using sensor networks for context awareness.

*Efficient dependable networked embedded systems*

The goal of this research is to provide system designers the means to enable efficient design of low-cost dependable systems. Kernel activities are: the development of testable design and debugging strategies for efficient MPSoC systems, the design of Design-for-Test (DfT) and Design-for-Debug (DfD) hardware and software supporting these strategies.

In the reporting period, the research has been focussed on *testing of asynchronous designs and dependable high-speed chips*. Energy efficiency in SoCs can be accomplished by using an asynchronous design approach, in contrast to the standard synchronous designs. However, asynchronous designs pose serious test problems, and hence jeopardize their quality and dependability. We worked on scan-based techniques with Philips Research, which are now used in commercial products and we designed Built-In Self-Test circuits for synchronizers in high speed SoCs for Alcatel. For dependability of high-speed chips, special test techniques have been developed. We reused the IEEE 1500 standard for Built-In Self tests for determining small internal delays.

The focus in the coming years will be on testable design, debugging and self repair of SoCs to obtain highly dependable systems. The applications areas will be networked embedded systems (wireless sensor nodes), SoC/NoCs for video applications, and heterogeneous SoCs.

**4. Processes in research, internal and external collaboration**

The general research vision we have is that a multidisciplinary approach is necessary as many of the identified challenges need to be addressed in an all inclusive way that considers systems,

environment and user in close correspondence. Therefore, in the research of the group fundamental research activities that address the need for new methods, models, and tools are interwoven with experimental projects. The multidisciplinary approach is another reason why there is a close cooperation with other groups.

There are monthly meetings with the permanent staff of the group. In a weekly meeting the group members, including MSc students, share technical presentations and discussions. In these meeting the PhD students also give feed-back of the conferences they visited: notify important trends and important papers for the group. The co-operation of PhD students is very much promoted, which can be seen in many joint publications. All PhD students have individual assignments but we advocate cooperation between students. Most students already work in a project together with others PhD students from other groups, but we also promote cross-project cooperation whenever possible. All papers written by PhD students are reviewed either by staff members or PostDocs. There are many joint projects with other groups in the CTIT in particular: DIES (Hartel), ICD (Nauta, Haartsen), SAS (Slump), DWMP (Hurink). The group plays a key role in the CTIT SRO U-Bricks (Building Blocks for Ubiquitous Computation and Communication). Smit is the leader of the CTIT SRO U-Bricks, which coordinates all the embedded systems research at the University of Twente.

Nationally there are also a number of activities: e.g. Havinga is the initiator and project leader of the National BSIK project Smart Surroundings, Havinga is leading the NIRICT SRA Ambient Intelligence. Kerkhoff is responsible for the NIRICT Design lab in Twente, focussing on the national SoC design & test infrastructure. The chair participates in the national research school ASCI. Internationally, the group participates in many EU projects, and works together with other research institutes e.g. University of Cambridge UK, and Bell Labs, Murray Hill NJ USA.

## 5. Academic reputation (we mention highlights only, omitting PC membership etc)

The CAES group is nationally and internationally leading in the development of energy-efficient reconfigurable architectures, ambient intelligence architectures and applications, and wireless sensor networks. Below some measure of reputation of the staff members:

*Prof. dr. ir. Th. Krol*

- **Chairman** of the "Twente Embedded Systems Initiative", (TESI)
- Member of the core-team "STW/Progress Embedded Systems Roadmap"

*Dr. ir. G.J.M. Smit*

- Leader of the CTIT SRO (Strategic Research Orientation) U-Bricks
- **Reviewer** for many projects for STW, NWO, the EU 5<sup>th</sup> and 6<sup>th</sup> Framework, ITEA and IWT Vlaanderen
- **Invited presentations:** Dagstuhl workshop on "Dynamically reconfigurable systems", April 2006, 7th International Symposium on System-on-Chip Tampere, 2005, ERSA'05 The International Conference on Engineering of Reconfigurable Systems and Algorithms, Las Vegas 2005, Philips Research colloquium, September 2004, IMEC colloquium, Leuven, June 2003

*Dr. ing. P.J.M. Havinga*

- **Editor of journals:** Associate Editor of the Journal "Ad hoc networks" (Elsevier) (since 2004), Associate Editor of the "Journal of Mobile Multimedia" (Rinton Press) (since 2004), Guest Editor of a special issue of IEEE Wireless Communications on sensor networks (December 2004).
- **Evaluator and reviewer** of many projects within the EU 5<sup>th</sup> and 6<sup>th</sup> Framework, ITEA, Medea+, NWO (since 2000), Evaluator of many projects for the Belgium, Italian, Israeli, and Austrian research councils (since 2000)
- **Program committee chairs:** ICWSN 2005, International congress for Wireless Sensors & Networks 2005, ISSNIP 2005, Intelligent Sensors, Sensor Networks and Information Processing, 10th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2005), EWSN 2005, 2nd European Workshop on Wireless Sensor Networks, INSS 2005, Second International Workshop on Networked Sensing Systems, DEST International Workshop on Signal Processing for Sensor Networks 2004

*Dr. Ir. H.G. Kerkhoff*

- **Member editorial board** of the Journal of Electronical Testing: Theory & Applications (JETTA)
- **Visiting professor** Interuniversity Research Center Microelectronics, ITB, Bandung, Indonesia (Summer 2003 and 2004).
- Expert **evaluator** & public authority of CEC, STW and IWT: e.g. MEDEA, MEDEA+, JESSI, FP3, FP4, FP5, FP6, USE

*Dr. ir. P.M. Heysters*

- One of the three nominees for the 2005 STW Simon Stevin Gezel price for outstanding valorization
- Founded Recore Systems B.V. Recore Systems has won the STW valorisation grant Phase 1 (2005) and Phase 2 (2006)

## 6. External validation

The group has directly resulted in two spin-off companies (Recore Systems and Ambient Systems). In Recore Systems three former group members (3 PhDs: Heysters, L.T. Smit and Rauwerda) bring the results of the Chameleon project (the Montium technology) to the market. Recore has an exclusive license on the Montium technology.

Three group members (Havinga, Dulman, and van Hoesel) have founded in 2004 the company Ambient Systems. This company is building upon the research performed in the group on networked embedded systems. The EU project EYES, lead by the group, has brought knowledge to the participants, and some of the results are already used in several products by the industrial participants.

A number of research results in the dependable area have been the basis for commercial usage, e.g. for Philips Research and Philips Semiconductors (Eindhoven, Nijmegen, Hamburg), Scan-based ATPG for asynchronous, TAM optimization.

### 6.a. Societal relevance

The results of the research on networked embedded systems will have a profound impact on the society. "... Intelligent functions embedded in components and devices will be a key factor in revolutionising industrial production processes, from design to manufacturing and distribution. These technologies add intelligence to the control processes in manufacturing shop floors and improve the logistic and distribution chains, resulting in an increasing productivity in a wide range of industrial processes. It is expected that soon everybody will be surrounded by hundreds / thousands of embedded systems ... " [excerpt from EU Artemis report]. Examples of networked embedded systems the group is working on are: handheld devices (e.g. mobile digital broadcast radio/TV receivers), wireless sensor networks (e.g. for environmental monitoring, personal health monitoring, logistics, shop floor management and safety critical systems (e.g. disaster management)). Given the importance of this field and the expertise of the group the staff members are often asked for presentations for industry and academic fora.

Kerkhoff has provided several invited full tutorials on testable design at international conferences. Molenkamp is member of the IEEE-DASC (Design Automation Standards Committee) and is active in the standardization of several IEEE standards (draft std. 1076-2006, IEEE Std. 1076.6-2004). He also gives on a regular basis VHDL courses for the industry, directly, or via PATO (Post Academisch Technisch Onderwijs).

The group performs research in a highly relevant field. This can be seen in the amount of industry sponsored PhD positions: in 2006 4 PhD are sponsored by Philips Research/NXP, 1 PhD sponsored by Essent/Gasunie, 1 PhD sponsored by Thales Hengelo, and 1 PhD sponsored by Philips Medical Systems.

### 6.b. Industrial contacts

In this list we only provide the industrial contacts with which we work together in projects. There are more contacts e.g. via student projects.

Philips Research (different groups in Eindhoven), Philips Semiconductors/NXP (Eindhoven and Nijmegen), Philips Medical Systems (Best), Thales Communications (Paris, Hengelo and Huizen), Silicon Hive (Eindhoven) Recore Systems (Enschede), Ambient Systems (Enschede), Atmel Germany (Ulm), PACT (Munich), IMEC (Leuven), DICAS (Berlin), WMC (Enschede), Nedap (Gronlo), TNO (Eindhoven, Den Haag), HOMA Software (Enschede), Essent (Deventer), Gasunie/Gasterra (Groningen), Maser Engineering (Enschede), Salland Engineering (Zwolle), Advantest (Munich), Alcatel (Antwerp), LioniX, STC (USA), QinetiQ (UK), MultiSynTech (Germany), IBM (Zurich, Amsterdam), LogicaCMG, Chess (Haarlem), BP (UK), SAP (Germany), Infineon Technologies, EADS (France), Siemens (Italy), Selex (UK), Flying-Cam (Belgium), Iturri (Spain).

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Krol, Prof.dr.ir. Th.	0,76	0,76	0,04
associate professor (uhd)	Havinga, Dr. P.J.M.			0,4
	Kerckhoff, Dr.ir. H.G.	0,4	0,4	0,4
	Smit, Dr.ir. G.J.M.	0,4	0,4	0,4
assistant professor (ud)	Havinga, Dr. P.J.M.		0,4	
	Kokkeler, dr.ir. A.B.J.	0,3	0,4	0,4
	Molenkamp, Ir. E.	0,8		
other junior staff (moz, twaio)	Rosien, Ir. M.A.J.		0,34	0,46
<b>Total tenured staff</b>		<b>2,66</b>	<b>2,7</b>	<b>2,1</b>
professor (hgl)	Krol, Prof.dr.ir. Th.			0,34
postdoctoral fellows	Dulman, S.O.			0,17
	Heysters, ir. P.M.		0,5	0,95
	Lijding, dr. M.E.M.		0,42	0,5
	Mahmud, K.		0,08	
	Mansour, ir. O.		0,25	0,41
	Meratnia, N.			0,84
	Smit, dr.ir. L.T.		0,92	1,0
	Zwaag, Ir. B.J. van der			0,5
junior staff (aio, oio, moz-p)	Arun, A.J.	0,8	0,68	0,06
	Beest, Ir. F.J. te	0,07		
	Burgwal, M.D. van de			0,34
	Chatterjea, S.			0,8
	Dulman, S.O.	0,8	0,8	0,66
	Evers, ir. L.		0,23	0,8
	Fang, L.	0,19		
	Gemesi, R.		0,26	0,8
	Guo, Y.	0,8	0,8	0,8
	Heysters, ir. P.M.	1,0	0,4	
	Hoesel, ir. L.F.W. van	0,4	0,4	0,8
	Holzspies, ir. P.K.F.			0,13
	Muthukrishnan, ir. K.		0,31	0,8
	Khatib, M.G.		0,03	0,4
	Mansour, ir. O.	1,0	0,75	
	Marin Perianu, M.		0,13	0,8
	Petre, O.	0,8		
	Rauwerda, ir. G.K.	0,8	0,8	0,8
	Smit, dr.ir. L.T.	1,0	0,08	
	Stancic, M.	0,13		
	Vermaak, H.J.	0,8		

Name and present title	2003	2004	2005
Visser, Ir. B.S.	0,4		
Wiggers, ir. M.H.			0,8
Wolkotte, ir. P.T.	0,13	0,8	0,8
Wu Jian, W.J.	0,8	0,8	0,8
Zhang, Q.		0,07	0,8
other junior staff (moz, twaio)			0,78
Adiono, T.			0,14
Burgwal, M.D. van de			0,8
Cotaimich, P.M.		0,34	0,8
Hofmeijer, T.J.			0,8
Rosien, Ir. M.A.J.	0,34	0,46	
<b>Total non-tenured staff</b>	<b>10,26</b>	<b>10,31</b>	<b>18,43</b>
<b>Total Research staff</b>	<b>12,92</b>	<b>13,01</b>	<b>20,54</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

CAES is coordinator for the institute participation in Europractice. Hence, we have Europractice CAD tools for chip design (e.g. Cadence, Sysopsys, CoWare and Mentor Graphics) and testing (Synopsys). In addition we have full access via Europractice to advanced chip foundries (e.g. AMS, 0.18um UMC). CAES has a full range of process testing sites (e.g. CV, IV), analogue test bench equipment (e.g. full RF range) and mixed-signal verification ATE (Credence/IMS ATS2, 200MHz, AWG & digitizers high-resolution/high-speed). It is anticipated that the NIRCT Design lab in Twente will extend this activities to a national (3TU) level.

### 8.b. FTE-funding PhDs/postdocs

Table 5

Funding	2003	2004	2005	Average
Direct funding	8%	20%	28%	19%
Research funds	60%	29%	27%	39%
Contracts	32%	51%	45%	43%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

### 8.c. List of external funds

Table 6

Name project	Start	End	Sponsor
License Agreement Montium Technology	1-10-2005	31-12-2006	ATMEL SARL
4S: Smart Chips for Smart Surroundings	1-1-2004	1-10-2007	European Commision
CoBiS: Collaborative Business Items	1-8-2004	1-2-2007	European Commision
Embedded WiSeNts: Wireless Sensor Networks -- Omnipresent Embedded Systems for Exploration and Control	1-9-2004	31-12-2006	European Commision
PATENT-DfMM: Design for Micro and Nano Manufacture - Network of Excellence	1-1-2004	1-1-2008	European Commision
EYES: Energy-Efficient Sensor Networks	1-3-2002	1-3-2005	European Commision
DATOS: Design And Test Of Systems-on-chip	1-1-2003	1-5-2005	KNAW
Seamless Services	1-3-2001	1-3-2004	NORUT Information Technology
Consensus: Collaborative Sensor Networks	26-3-2003	26-3-2007	NWO

<i>Name project</i>	<i>Start</i>	<i>End</i>	<i>Sponsor</i>
Gecko: Communication and Scheduling in Reconfigurable Multimedia	16-1-2002	16-1-2006	NWO
C-Specification Heterogeneous Architectures	1-4-1998	1-4-2003	Philips Research Laboratories
PASTA: modelling PArallel Systems for Timing Analysis	1-1-2005	31-12-2008	Philips Research Laboratories
Freeband/AAF: Data communications in emergency situations through Cognitive Radio	1-1-2004	1-1-2009	SENER / BSIK
Smart Surroundings	1-1-2004	1-1-2009	SENER / BSIK
A4: Adaptive non-volatile storAge systems for Adaptive Applications	1-1-2004	1-12-2008	STW
ASYNCR: Testable Design and Testing of Asynchronous Circuits	1-8-1999	1-1-2004	STW
Chameleon: Reconfigurable computing in hand-held multimedia computers	1-12-1999	31-12-2004	STW
Featherlight Distributed Systems: A platform for the next generation of ambient systems	1-9-2004	1-9-2008	STW
Freeband/AWGN: Adaptive Wireless Networking	1-9-2002	1-4-2007	STW
High2: High-level synthesis tools for high-throughput digital systems applications	1-10-2000	1-10-2004	STW
Structural Fault Model	1-1-1997	1-3-2003	STW
Valorisation Grant: Karma Chameleon	1-9-2005	1-3-2006	STW

## 9. Overview of the results

### 9.a. Description of scientific results

In the area of streaming architectures we developed a reconfigurable multi-processor SoC (MPSoC) template called Chameleon and a coarse grain reconfigurable core called Montium.

The size of the Montium core processor is, in 0.13  $\mu\text{m}$  CMOS technology, only 2  $\text{mm}^2$ . It can be used as a building block for energy-efficient MPSoCs, because it combines processing and memory in one tile.

We have shown that for typical DSP algorithms like an FFT the Montium consumes 10 times less energy compared to an industry standard low-power ARM processor.

We were the first to design and publish a small and efficient NoC (Network-on-Chip) with a predictable performance (guaranteed throughput and bounded latency) that can be used in run-time reconfigurable MPSoCs for adaptive applications.

In the area of Wireless Sensor Nodes the group has a worldwide visibility. The group initiated the first project in Europe focusing on wireless sensor networks (Eyes). The group developed the first data centric Operating System for resource poor devices working in a dynamically changing environment. Major contributions were made to distributed localization algorithms and distributed resource management for self-organizing sensor networks.

In the area of dependable networked embedded systems major contributions have been made to the test of asynchronous circuits. It has resulted in an efficient industrially-used scan and BIST structure for detecting very small delays. In the mixed signal domain we were the first to publish an analog extension for the P1500 core-based testing standard and showed its operation in a SoC.



**9.b. Key publications**

Table 7

nr	Title
1	H.G. Kerkhoff and M. Acar, "Testable Design and Testing of Micro-Electro-Fluidic Arrays", in Proc. VLSI Testing Symposium (VTS), ISBN 0-7695-1924-5, Nappa, USA, April 2003, pp. 12A:1-7.
2	Lodewijk van Hoesel, Tim Nieberg, Jian Wu, Paul Havinga. "Prolonging the Lifetime of Wireless Sensor Networks by Cross-layer Interaction", <i>IEEE Wireless Communication</i> , communications 11 (nr: 6), (2004). (pp. 78-86) ISSN: 1536-1284
3	Rauwerda, G.K. and Heysters, P.M. and Smit, G.J.M. "Mapping Wireless Communication Algorithms onto a Reconfigurable Architecture.", <i>Journal of Supercomputing</i> , 30 (3). pp. 263-282. ISSN 0920-8542, 2004
4	Guo, Y. and Smit, G.J.M. and Heysters, P.M. and Broersma, H.J. "A Graph Covering Algorithm for a Coarse Grain Reconfigurable System", In <i>Proceedings of ACM-LCTES Conference on Languages, Compilers, and Tools for Embedded Systems 2003</i> , San Diego, USA. pp. 199-208, ISBN: 1-58113-647-1.
5	Kokkeler, A.B.J. (2005) "Feedback Quantization in Crosscorrelation Predistorters". <i>IEEE microwave and Wireless Components Letters</i> , 15 (9). pp. 552-554. ISSN 1531-1309, 2005

**9.c. Numerical overview of the results in a fixed format of categories**

Table 8

		2003	2004	2005
1 Academic publications	a. PhD-theses	2	2	4
	b. in refereed journals	7	7	5
	c. international conference proceedings	24	35	42
	d. books			1
	e. book -chapters	1		3
<b>Total</b>		34	44	55
2. International patents				1

**9.d. Full outcome list****2003***PhD-theses*

Beest, F.J. te Full scan testing of handshake circuits. (2003, mei 21). 150 pp. Enschede, The Netherlands Twente University Press Thesis advisor(s): Prof.dr.ir. Th. Krol, Prof.dr.ir. C.H. van Berkel, Dr.ir. H.G. Kerkhoff. ISBN: 9036519098

Fang, L. System-level Testing of Embedded Analogue Cores in SoC. (2003, juni 12). 124 pp. Enschede, The Netherlands Twente University Press Thesis advisor(s): Prof.dr.ir. Th. Krol, Dr.ir. H.G. Kerkhoff. ISBN: 9036519195

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Berkel, K. van , Peeters, A., Beest, F.J. te Adding synchronous and LSSD modes to asynchronous circuits. *Microprocessors and microsystems* 27, (2003). (pp. 461-471) ISSN: 0141-9331

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**10. SWOT-analysis (excluding SWOT items already mentioned in part A)***Strengths*

- Active cooperation with other Ubricks chairs of the faculty EEMCS and other research institutes
- Excellent knowledge transfer to industry (e.g. spin-off activities, in depth tutorials)
- Good PhD candidates can be recruited from our own MSc students

*Weaknesses*

- Given the interest we have from industry our work is very relevant, however, our publications are not very often cited; because our work is used by development engineers in industry who do not publish much in scientific journals
- Relatively few dissertations in the first years of the reporting period, but the number is growing

*Opportunities*

- There are ample opportunities for funding of research in networked Embedded Systems: e.g. nationally STW, Point-One, and internationally EU-FP7 Artemis. The research theme of the group is one of the focus areas of the CTIT and EU-FP-7.
- Energy-Efficiency and dependability has long been neglected in some areas of research and product development and therefore there are interesting opportunities.

*Threats*

- The group has grown considerably in this period; the quality of the research needs to be maintained
- Too wide research area

*Analyses*

- Regarding the threats we have the policy to appoint temporary PostDocs in our group to support the staff members. One of the threats of the group (wide scope) is also one of our strengths; we need to have a broad scope because energy-efficient systems design requires a holistic view.

**Title of the chair's program:**

Design and Analysis of Communication Systems (DACs)

**Subprogrammes or themes:** none**NABS code:** N07**Chairman:** Prof.dr.ir. B. R. Haverkort**Starting dates of (each sub-) program:** January 1, 2003**Formal affiliations outside the department and other formal co-operations:** none

*The DACs program started with the appointment of professor Haverkort beginning 2003. The period 2003-2005 can be characterised as a period of change in which existing obligations were finished, and a new programme was developed. Four out of five of the tenured faculty comprising DACs at this moment, were appointed during the period 2003-2005. None of the temporary research staff that was present in 2002, was still present at the end of 2005.*

**1. Mission statement**

DACS focuses on *dependable networked systems*. A (networked) system is called dependable, whenever reliance can justifiably be placed on the services it delivers. Tailored to communication systems, which can be wired, wireless, or embedded in other systems, this means that we aim:

**'To contribute to the design and implementation of dependable networked systems, as well as to methods and techniques to support the design and dimensioning of such systems, such that they are dependable, in all phases of their lifecycle.'**

We thereby interpret the term dependability as encompassing availability, reliability, performance (quality of service) and security.

**2. Leadership**

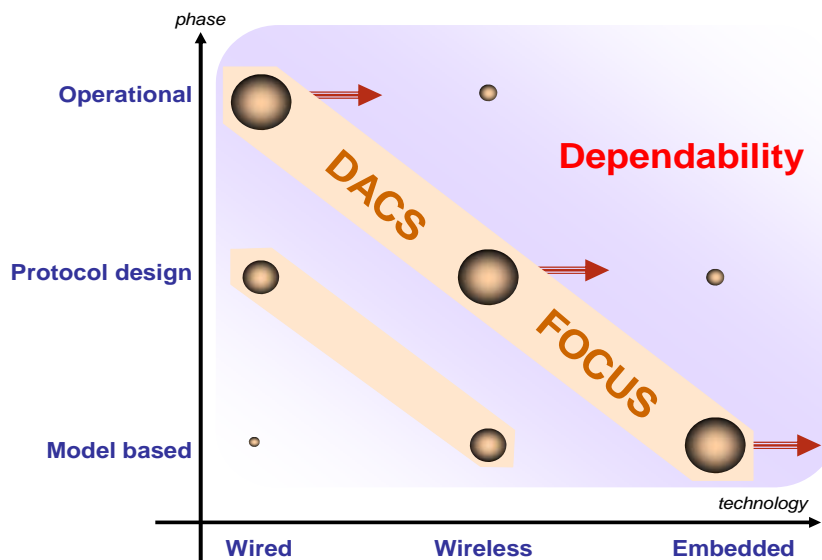
The DACs group is headed by the full-time professor Haverkort (chair holder) who is ultimately responsible for the group. A three-person management team, consisting of the chair holder and the two associate professors (Heijenk and Pras) meets typically once per month, to handle and discuss organisational, financial and administrative issues. These three persons are also responsible for setting out the main lines of research (cf. section 3). Next to that, the staff has a monthly lunch meeting, in which plans, possibilities and problems with respect to research, teaching, and organisational affairs are discussed. The staff lunch has an informal nature; typically, in a single staff lunch, the focus is on a single topic only.

Information dissemination within the group goes along the line chair holder—staff member—postdoc & PhD student. No plenary organizational group meetings are held. A plenary colloquium is held every month, in which primarily PhD students (as well as new group members) present their work. The colloquium is also used for information dissemination purposes. All staff members have an open door policy.

**3. Strategy and policy****3.a. Design in brief**

*Three phases in system design.* We distinguish three phases in the design of dependable networked systems. In the first (exploratory) phase the emphasis lies on the development of system models and the model-based evaluation of key system characteristics. In the second, more concrete phase the emphasis lies on designing and/or standardizing systems architectures, protocols, and algorithms, as well as on implementing prototype systems. In the third, operational phase the systems have been implemented and the emphasis lies on operationally managing them. As an example of these three phases, consider the internet backbone. During 1965-1985, research concentrated on a variety of networking models

(circuit-switching vs. packet-switching, various local area access mechanisms). In the period 1980-1995, research focus shifted toward designing, implementing and standardizing protocols (TCP/IP, Ethernet). Since the beginning of the 1990s, an ever more important challenge is to keep the internet up and running, and solve problems related to (performance) management, security and scalability. A similar transition in focus can be seen for wireless communication system. The figure below illustrates, through a horizontal structuring, the above three phases in system design.



**Three technologies for dependable networked systems.** Within DACS, research on wired networks (primarily internet) focuses on operational aspects, like managing and optimizing configurations, as well as on intrusion detection. Taking and interpreting measurements plays an important role in this research. In this area DACS also performs work on the design and standardization of new protocols, like NSIS (QoS signalling protocols for the internet).

Research on wireless systems focuses on the design, evaluation and prototype implementation of new protocols and algorithms, such as algorithms for context- and power-aware routing in ad-hoc networks, personal network architectures, security in personal networks, as well as on service discovery architectures and algorithms.

Finally, research on embedded networked systems focuses primarily on system specification and evaluation techniques to describe such systems and the resource constraints they have to operate under. This includes the development of new stochastic model checking techniques and the application thereof to predict dependability and performance properties.

The figure above also shows, through a vertical structuring, the three technology domains (where a clear cut separation can, of course, never be made). When technologies mature over time, a shift in phase and type of activity is foreseen. Inherent to university research, DACS moves on the increasing side of the wave (to the right).

### 3.b. Programme development

The view toward the research within DACS as explained above, has been developed over the last year. Each of the three areas has as coordinator a full or associate professor: Pras for dependable operational network systems, Heijenk for (protocol) design of dependable network systems, and Haverkort for model-based issues in dependable networked system design. Each

of these area coordinators has a very clear presence in the respective international scientific community (e.g., as regular conference organiser, PC chair, and journal editorial board member). These three focal points will be further developed and emphasized in the years to come. More than in the past, we will ask the question how new activities fit in, before we take them up.

Notice that the presented structure is a structure based on technical content, not an organisational sub-structuring of the group. Group members participate in a variety of projects, in which all the above issues might play a role.

Currently, the group is actively involved in the CTIT strategic research orientations (SROs) on "A-services Internet" (networking), "U-BRICKS" (embedded systems) and "Istrice" (security). For the near future, we envisage (and will strive for) an SRO on "dependability for ICT", in which a larger share of our current work can be put forward.

There are a number of internal and external developments that will have their impact on the further development of DACS:

1. In the course of the 3TU federation process, the UT NIRICT initiative (Netherlands Institute for Research in ICT) has acquired the status of Centre of Competence (lead by professor Apers, also director of CTIT). Within NIRICT, the Centre for Dependable ICT Systems (CeDICT) has been established mid 2006, as one of the six new centres of excellence between the three TU's in the Netherlands. DACS is effectively leading the efforts to set up CeDICT as *the* national expertise centre for dependability research.
2. The DACS group is one of the participants in the TNO Expertise centre on Quality of Service, called "E-Quality". DACS parttime professor Van den Berg is leading this centre, which focuses on mechanisms and analysis of QoS support (including issues of dependability) in wireless networks and large-scale distributed systems.
3. The CS department at the UT has a strong focus on security. We will become more active in this area as well, where we will focus on network security based on observation of network traffic and traffic measurements (so-called anomaly-based intrusion detection).

#### **4. Processes in research, internal and external collaboration**

PhD students meet typically once per week with their daily advisor. The daily advisor always is one of the tenured faculty, possibly supported by a postdoc. When the full professor is not the daily advisor, meetings between the PhD student and full professor are less regular in the beginning years, but become much more intensive in the second half of the PhD period as well. It is expected that for a successful PhD student, 4-5 conference (or journal) publications are produced and submitted to full-review high-quality conferences.

Since the three area coordinators within DACS are prominent and respected researchers in their respective world-wide communities, they have the possibility to let their PhD students involve actively in all important scientific processes (e.g., in the review process for major the conferences and journals (on which they serve on editorial boards) and to introduce them to other key players in the field (e.g., by arranging visits or to bring them in contact with fellow PhD students from other institutions). This provides the PhD students the possibility to acquire an "inside view" and to become active members of the international scientific community themselves. Active participation in conferences requires that PhD students submit quality papers to these conferences; this is strongly encouraged. In the beginning period, a PhD student is typically allowed to attend one or two (international) conferences without presenting own work, to get acquainted with the atmosphere and the way things work.

All tenured staff is involved in teaching, also the chair (who lectures, among others, in the first year of the BSc programme). PhD students and postdocs are actively supporting the educational processes, e.g., by guiding BSc and MSc students in individual assignments, by "running" exercise hours or in supervising literature search assignments.

The senior staff typically take the lead in external project acquisition, sometimes supported by the more junior tenured staff and the postdocs. Since 2005, the tenured staff is encouraged to make plans for a 2/3-month sabbatical. As a result of this, Pras went on sabbatical in 2006 (INRIA, Nancy, France), whereas concrete plans have been made for De Boer for early 2006 (IRISA, Rennes, France). Heijenk and Haverkort will probably take sabbaticals in 2007 or 2008 as well.

Among the PhD students and postdocs, more than 75% is of non-Dutch origin. We are very pleased to say that more than 50% of our postdocs and PhD students is female (but none of these is Dutch).

## 5. Academic reputation (we mention highlights only, omitting PC membership etc)

### *Prof.dr.ir. B.R. Haverkort*

- General Chair, IEEE Conference on "Quantitative Evaluation of Systems 2004", Enschede, the Netherlands, 2004.
- TPC chair, IEEE/IFIP Conference on "Dependable Systems and Networks 2005", Yokohama, Japan, 2005.
- Member, IFIP WG 6.3 "Performance of Communication Systems", since 1998.
- Member, IFIP WG 7.4 "Computer Performance Modelling and Analysis", since 2005.
- Leading role in the 3TU Centre of Excellence CeDICT, since 2006.
- Board member, Dutch research school ASCI, since 2005.
- Editorial board member, "Performance Evaluation", since 2005.
- Steering Committee chair, Int'l. Workshop on Performability Modelling of Computer and Communication Systems, since 2000.
- Steering Committee member, GI/ITG-Fachgruppe "Messung Modellung und Bewertung von Rechen- und Kommunikationssysteme", since 2001.
- Steering Committee member, Int'l. Conference on Quantitative Evaluation of Systems, since 2003.
- Fellow of the IEEE, as of 2007.
- PhD student A. Bell and MSc student A. Remke received the German GI/MMB prize for their best theses, in 2004, resp. 2005.

### *Dr.ir. G.J. Heijenk*

- Member, COST 290 "Traffic and QoS in Wireless Multimedia Networks", since 2006.
- Editorial board member, Journal of Internet Engineering, since 2006.
- Senior member IEEE, since 2006.
- PhD student R. Ait Yaiz won the KIVI/NIRIA Telecommunication prize, 2005.

### *Dr.ir. A. Pras*

- TPC chair, 2nd and 3rd IEEE/IFIP Workshop on End-to-End Monitoring Techniques and Services, Nice, France, 2005, resp. Vancouver, Canada, 2006.
- TPC chair, 9th IFIP/IEEE International Symposium on Integrated Network Management, 2005, Nice, France.
- Member, IFIP WG 6.6 "Management of Networks and Distributed Systems".
- Series Editor, IEEE Communications Magazine for Network & Service Management, since 2004.

### *Dr.ir. S.M. Heemstra de Groot*

- Vice general chair, 9th Int'l. Conference on Personal Wireless Communications 2004, Delft.
- TPC co-chair, 1st Int'l. Workshop on Personalized Networks, July 2006, San Jose, USA.
- Marina van Damme Award for female entrepreneurs, November 2003.
- Member IST Advisory Board for the European Security & Dependability Task Force.
- Member IFIP TC6 working group on "Personal Wireless Communication".

*Prof.dr. J.L. van den Berg*

- KPN Diana Telecommunication prize, 2003.
- Member, COST 290 "Traffic and QoS in Wireless Multimedia Networks", since 2006.
- Elevated to Senior Research Fellow within TNO, 2005.
- Member, IFIP WG 6.3 "Performance of Communication Systems".
- Editorial board member, Telecommunication Systems Journal.

*Prof.ir. A.C. van Bochove*

- Board Member, Benelux Chapter, IEEE Lasers & Electro-Optics Society, since 2001

*Dr.ir. G. Karagiannis*

- Member IETF working group "Next Steps in Signaling"
- Co-author of internet standard RFC 4080 "Next Steps in Signaling (NSIS): Framework", June 2005, 49 pages. <http://www.ietf.org/rfc/rfc4080.txt>

*Dr.ir. P.-T. de Boer*

- Steering committee member, Rare-Event Simulation workshop.
- Guest-editor for a special issue of Annals of Operations Research (2003).

**6. External validation*****6.a. Societal relevance***

DACS focuses primarily on the technical aspects of dependable communication systems. However, as such systems are omnipresent, there is a broad but indirect societal interest in our achievements. DACS takes its societal responsibility by also publishing in popular media and giving presentations for non-technical audiences. Examples include articles in *De Automatiseringsgids*, radio interviews, e.g., in "*HoeZo?*" on AM 747 (on embedded communication systems), and RTV-Oost (on issues related to UMTS antennas), presentations for radio amateurs on software defined radio, lectures about internet and its history for a Lions or Probus club, a presentation on UMTS technology for an ICT-business club meeting, as well as presentations in regional schools. A staff member of DACS also contributes to the organization of the annual Informatics Olympiad in the Netherlands.

***6.b. Industrial contacts***

Lucent/Bell Labs, Ericsson Rijen, Ericsson Research, Ericsson Eurolab Aachen, Vodafone, TNO-ICT, TI-WMC, KPN, Samsung, Thales Communications, Telematica Institute, Embedded Systems Institute.

Collaborations exist with a variety of international research labs as well, among others in the context of IETF, such as Alcatel, Roke Manor Research (UK), Cisco Systems (USA, France), Nortel (USA, Canada), Nokia (Finland), Sonus Networks (USA), AT&T (USA), Samsung (Korea), DoCoMo Euro-Labs (Germany), NEC (Germany), Ericsson Research (various countries), Hewlett-Packard (USA and UK).

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Haverkort, prof.dr.ir. B.R.H.M.	0,4	0,4	0,4
associate professor (uhd)	Heemstra de Groot, Dr.ir. S.M.	0,09	0,09	0,09
	Heijenk, Dr.ir. G.J.	0,23	0,4	0,4
	Nicola, Dr.ir. V.F.	0,34		
	Pras, Dr.ir. A.		0,14	0,4
assistant professor (ud)	Boer, Dr.ir. P.T. de	0,4	0,4	0,4
	Karagiannis, dr.ir. G.	0,29	0,4	0,4
<b>Total tenured staff</b>		<b>1,74</b>	<b>1,82</b>	<b>2,09</b>
professor (hgl)	Berg, prof.dr. J.L. van den	0,04	0,08	0,08
	Bochove, prof.ir. A.C. van	0,08	0,08	0,08
postdoctoral fellows	Kuntz, G.W.M.			0,08
junior staff (aio, oio, moz-p)	Ait Yaiz, Ir. R.	1,0	0,41	
	Cloth, dipl.-inf. L.	0,57	0,8	0,8
	Dey, D.	0,33		
	El Allali, Ir. H.	1,0	1,0	
	Fioreze, T.			0,27
	Goering, P.T.H.	0,13	0,8	0,8
	Jehangir, A.	0,4	0,8	0,8
	Kamilova, Msc M.		0,13	0,8
	Liu, F.		0,27	0,8
	Martinez Verdugo, J.M.	0,64	0,8	0,8
	Remke, Dipl.Inform. A.K.I.		0,3	0,8
	Salvador, MSc. M.R.	0,07		
	Taniman, Msc R.O.		0,67	0,8
	Zaburnenko, T.S.	0,8	0,8	0,66
	Abendroth, D.	0,26	0,06	
	Edigarian, G.	0,73		
other junior staff (moz, twaio)	Heijenk, Dr.ir. G.J.	0,07		
	Kamilova, Msc M.	0,27		
<b>Total non-tenured staff</b>		<b>6,4</b>	<b>7,0</b>	<b>7,57</b>
<b>Total Research staff DACS</b>		<b>8,14</b>	<b>8,83</b>	<b>9,66</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

All staff members have a normal office PC with either Linux or Windows for daily work. We have a networking laboratory with a variety of routers (Cisco, Cabletron), switches (HP, IBM, D-link) and several compute servers (running Linux and Xen), as well as a variety of PC's with multiple network cards which can be connected in different configurations, as well as virtualization software and hardware for personal network experimentation. In addition, DACS measurement equipment is currently installed at SURFnet and the ITBE (the group running the UT campus-wide network). Within the context of EMANICS, DACS experiments with trace analysis (SNMP, NetFlow), Podcasting and RSS feeds. Within the NWO project VeriGEM we use the ASCI distributed supercomputer (DAS) for very large scale model checking problems.



**8.b. FTE-funding PhDs/postdocs***Table 5*

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	48%	14%	9%	23%
Research funds	18%	16%	23%	19%
Contracts	35%	70%	69%	58%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

**8.c. List of external funds***Table 6*

<i>Name</i>	<i>Start date</i>	<i>End date</i>	<i>Sponsor</i>
E-NEXT: Network of Excellence Emerging Network Technologies	1-1-2004	1-7-2006	European Commision
Seacorn: Simulation of Enhanced UMTS Access and Core Networks	1-3-2002	1-3-2004	European Commision
EQUIP: Enabling Quality of Service in IP-Based Communication Networks	14-8-2001	31-1-2006	NWO
MC=MC: Model-Checking of Infinite-State Markov Chains	16-8-2004	16-8-2008	NWO
MOQS: Modeling and Analysis of QoS of Component-Based Designs	1-9-2005	1-12-2008	NWO
veriGEM: A Verification Grid for Enhanced Model Checking	1-12-2005	1-12-2008	NWO
Voss: Validation of Stochastic Systems	1-3-2001	1-1-2004	NWO
Voss-2: Validation of Stochastic Systems II	1-1-2005	1-1-2008	NWO
Optische Netwerken	1-9-1999	1-9-2003	PTT-Research ITB
Bluetooth Networking	1-4-1999	1-12-2003	SENTER Novem / BSIK
Freeband/Awareness: context AWARE mobile NETworks and ServiceS	1-1-2004	1-1-2009	SENTER Novem / BSIK
Freeband/PNP2008: Development of a user centric ambient communication environment	1-1-2004	1-1-2009	SENTER Novem / BSIK
FSAN: Full-service Access Network using Multimode Fibre	1-3-2004	1-3-2008	SENTER Novem / IOP
PN@H: Quality of Service for Personal Networks at Home	1-9-2003	1-9-2007	SENTER Novem / IOP
Q-Wing: Quality of Service in the Wireless Internet Next Generation	1-1-1999	31-12-2003	SENTER Novem
FLAMINGO: Flexible Multiwavelength Optical Local Access Network Supporting Multimedia Broadband Services	7-3-1998	7-3-2003	STW
Gigaport: Research on Networks	1-1-2005	31-12-2007	SURFNET
E-Quality: Expertise Centre on Performance and Quality of Service in ICT	1-12-2005	1-12-2009	TNO-FEL

**9. Overview of the results****9.a. Description of scientific results**

Among our achievements over the period 2003-2005 we count:

1. Complete development & characterisation of CSL and CSRL model checking algorithms for evaluating performance and dependability properties of networked systems; these algorithms are now used in a variety of software tools and the papers on these topics are often cited.

2. Development and analysis of a scheduling mechanism for wireless CDMA-based systems. The mechanism (Fair Channel Dependent Scheduling) is being patented and implemented by Ericsson, and various papers have been published on the idea.
3. Development of a framework and protocols for resource management in DiffServ-based networks. The concept is widely published, a number of patents on parts of the concepts are requested (by Ericsson), and the ideas are under standardisation in the IETF NSIS Working Group.
4. Development of a rich set of analytically tractable models for the analysis of wireless access protocols, in particular IEEE 802.11 ("WLAN") and the application thereof in the context of ad hoc networks.
5. Advances in the field of rare-event simulation of complex queuing network models with application to communication system dimensioning.

### 9.b. Key publications

Table 7

<i>nr</i>	<i>Title</i>
1	C. Baier, B.R. Haverkort, H. Hermanns, J.-P. Katoen, Model-Checking Algorithms for Continuous-Time Markov Chains. IEEE Transactions on Software Engineering 29(6), 524-541, 2003, ISSN: 0098-5589 .
2	R. El Abdouni Khayari, R. Sadre, B.R. Haverkort, Fitting world-wide web request traces with the EM-algorithm. Performance Evaluation 52(2-3), 175-191, 2003, ISSN: 0166-5316.
3	J. Schönwälder, A. Pras and J.P. Martin-Flatin, On the future of Internet Management Technologies, IEEE Communications Magazine, 41(10), 90-97, 2003, ISSN: 0163-6804.
4	P.T. de Boer, D.P. Kroese, S. Mannor, R.Y. Rubinstein, A Tutorial on the Cross-Entropy Method, Annals of Operations Research, 2005, pp. 19-67, ISSN: 0254-5330.
5	R. Ait Yaiz and G.J. Heijenk, Providing QoS in Bluetooth. Cluster Computing, 8 (2-3): 223- 231, 2005. (ISSN 1386-7857)

### 9.c. Numerical overview of the results in a fixed format of categories

Table 8

		2003	2004	2005
1 Academic publications	a. PhD-theses	2	2	
	b. in refereed journals	4	4	13
	c. international conference proceedings	11	14	36
	d. books			
	e. book -chapters		1	2
<b>Total</b>		17	21	51
2. International patents		1		

**9.d. Full outcome list****2003***PhD-theses*

- Dey, D. Towards an all-optical WDM slotted-ring MAN with support for optical multicasting. (2003, juni 19). 164 pp. Enschede, The Netherlands University of Twente Thesis advisor(s): prof.ir. A.C. van Bochove, Prof.ir. A.M.J. Koonen. ISBN: 90-365-1930-6
- Salvador, M.R. MAC protocols for optical packet-switched WDM rings. (2003, januari 31). 186 pp. Enschede, The Netherlands University of Twente Thesis advisor(s): Prof.dr.ir. I.G.M.M. Niemegeers. ISBN: 90-365-1862-8

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- Mei, R.D. van der , Vranken, R., Gijsen, B.M.M., Berg, J.L. van den Sojourn time approximations for a multi-server processor sharing system with priorities. Performance evaluation (2003). (pp. 249-261) ISSN: 0166-5316

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- Ait Yaiz, R. , Heijenk, G.J. Providing Delay Guarantees in Bluetooth. Proceeding of the 23rd international conference on Distributed Computing Systems Workshops (2003). 7 pp. Providence, Rhode Island, USA
- Bruin, I. de , Heijenk, G.J., El zarki, M., Zan, J.L. Fair Channel-Dependent Scheduling in CDMA Systems. IST - Mobile & Wireless Communications Summit 2003 (2003, juni 15 / 2003, juni 18). 5 pp. Aveiro ISBN: 972-98368-1-7
- Endrayanto, A.I. , Berg, J.L. van den, Boucherie, R.J. Characterizing CDMA downlink feasibility via effective interference. Proceedings on Performance Modelling and Evaluation of Heterogeneous Networks (2003, juli 21 / 2003, juli 23). 11 pp. Ilkley, West Yorkshire, United Kingdom
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- Khayari el Abdouni, R. , Sadre, R., Haverkort, B.R.H.M., Pistorius, M. A Class-Based Least-Recently-Used Caching Algorithm for WWW Proxies Proceedings. 13th Intl. Conference on Modelling Techniques and Tools for Computer Performance Evaluation Lecture notes in computer science 2794, (2003, september 2 / 2003, september 5). (pp. 273-290) Illinois, USA ISBN: 3-540-40814-2 / ISSN: 0302-9743
- Lassila, P. , Berg, J.L. van den, Mandjes, M.R.H., Kooij, R.E. An integrated packet/flow level model for TCP performance analysis. Providing Quality of Service in Heterogeneous Environments (2003, augustus 31 / 2003, september 5). (pp. 651-660) Amsterdam Elsevier ISBN: 0-444-51455-4
- Litjens, R. , Roijers, F., Boucherie, R.J., Berg, J.L. van den, Fleuren, M.J. Performance analysis of WLANs: an integrated packet/flow level approach. Providing Quality of Service in Heterogeneous Environments (2003, augustus 31 / 2003, september 5). (pp. 931-940) Berlin, Germany Elsevier Science B.V. ISBN: 0-444-51455-4

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- Kalden, R.A. Mobile Internet traffic measurement and modeling based on data from commercial GPRS Networks. (2004, december 3). 200 pp. Aachen Druck und Verlagshaus Mainz GmbH Aachen Thesis advisor(s): prof.dr.ir. B.R.H.M. Haverkort. ISBN: 3-86130-752-9

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Barcelona, Spain Springer Verlag ISBN: 3-540-29388-4 / ISSN: 0302-9743  
Zaburnenko, T.S. , Nicola, V.F. Efficient heuristics for simulating population overflow in tandem networks. Proceedings of the 5th St. Petersburg Workshop on Simulation (2005, juni 26 / 2005, juli 2). (pp. 755-764) St. Petersburg ISBN: 5-96510102-3

*Books - chapter*

Berg, J.L. van den Traffic Measurement, Characterization, and Modeling. Analysis and design of advanced multi-service networks supporting mobility, multimedia and internetworking (2005). 251 pp. Berlin, Germany Springer Verlag ISBN: 0-387-28172-X  
Parhonyi, R. , Nieuwenhuis, L.J.M., Pras, A. The rise and fall of micropayment systems. Handbuch E-Money, E-Payment & M-Payment (2005). (pp. 343-361) Heidelberg Springer Verlag ISBN: 3-7908-1651-5

**10. SWOT-analysis (excluding SWOT items already mentioned in part A)**

*Strengths:*

- three clear research lines with well-visible leading researchers
- restructuring process over the last 3 years, leading to a better focused group
- well-cited scientific output
- well positioned in 3TU federation process
- ability to attract funding from high-quality sources

*Weaknesses:*

- very good research in all three areas, but interaction can be improved

*Opportunities:*

- 3TU federation process allows us to become the leading group in the Netherlands on dependable communication systems
- improvement process set in, in involving more staff members in the process of project acquisition and PhD student guidance

*Threats:*

- fragmentation of time of staff members over many projects and different areas
- UT-internal financial/organizational overhead
- 3TU federation process forces us to make choices, which always implies a risk



**Title of the chair's research program:**

Distributed and Embedded Systems (DIES)

**Sub-programmes or themes:** none**NABS code:** N07**Chairman:** Prof.dr. P.Hartel**Starting dates of (each sub-) program:** none**Formal affiliations outside the department and other formal co-operations:** none**1. Mission statement**

Distributed and embedded systems are resource constrained, dynamically evolving, unattended systems, which interact with a physical environment with the ultimate purpose of serving people (Smart Systems). Examples of the applications we work on include wireless sensor systems, home networks, and information systems. Our mission is:

**'To foster systematic reasoning about the fundamental properties of distributed and embedded systems'.**

We are interested in security en dependability properties because threats and faults are huge practical problems, whereas the solutions require sophisticated theory, advanced tools and extensive experimentation.

**2. Leadership**

The group is managed by the senior research active staff (Hartel, Etalle, and at a distance Mullender), with frequent informal consultation of other staff. Formal group meetings with all academic staff and PostDocs involved in lecturing take place 3 or 4 times a year. In the past six years, DIES has been successful in acquiring external research funding, and getting papers accepted in high quality conferences and journals. We believe that this success is due to extensive cooperation within the group and with other groups (CAES, DB, FMT, IS, SMI and SAS). This success provides intrinsic motivation for group members to collaborate even more. Etalle is the leader of the CTIT SRO Istrice and the University Potential Program Prosecco; this constitutes the largest multidisciplinary security research group in the Netherlands. The synergy created by these two activities contributes to the success of the group, both locally, nationally and internationally.

**3. Strategy and policy*****3.a. Design in brief***

Currently, our research focuses on three classic system properties: *reliability* (continuity of correct service), *integrity* (absence of improper system and data alterations), and *confidentiality* (absence of unauthorised disclosure of information). Reliability is a dependability property, confidentiality is a security property, and integrity is both. We are increasingly interested in an aggregate property, *accountability*, which expresses that participants in a transaction are held responsible for their actions, being required to justify and explain their behaviour. Accountability is a security property.

The interplay between resource constraints, dynamics, unattended operation and the four properties listed above provides for a rich area of research. The challenges we face include:

1. To advance our theoretical and practical knowledge of designing dependable and secure systems. For example, our current understanding of smart systems is so limited that the best we can do today is to build systems and to subject them to experiments.
2. To take modelling dependable and secure systems and their environment from art to science. For example, it is relatively easy to make a different model for each different property of a system, or for a different purpose (analysis, optimisation, simulation). It is hard to keep those models consistent.

3. To develop methods and tools supporting a holistic view of systems. For example, many properties are delicate: only one bottleneck may be sufficient to spoil the reliability, and one leak is sufficient to spoil the confidentiality of a system.
4. To develop new protocols and algorithms to improve the properties listed above of systems under stringent conditions such as resource constraints, dynamics, and unattended operation.

### 3.b. Programme development

In the context of the CTIT SRO ISTRICE, we work on integrity and confidentiality in distributed and information systems; in the context of the CTIT SRO UBRICKS we work on reliability and integrity in distributed and control systems. Distributed systems & integrity are thus common areas of interest. In the context of the EEMCS faculty we work on smart systems design. Much of our research is done by PhD students and PostDocs, under supervision of academic staff. Therefore we present an overview of our research by listing the PhD students who have recently graduated or who are about to graduate in the near future.

Student (date)	Reliability & Integrity	Integrity & Confidentiality	
Information Systems	Lenzini (2005), Zambon	Dekker, Czenko, Brinkman (2007), Zych	ISTRICE
Distributed Systems	Lijding (2003), Sundramoorthy (2006), Kavaldjiev (2007) Marin, Durmaz, Khatib	Chong (2005), Law (2005), Corin (2006), Bolzoni, Buhan, Akkiraju	
Control Systems	Kuiper, Marincic		

## 4. Processes in research, internal and external collaboration

All PhD students are supervised by an academic often with assistance from one or more of the PostDocs. All papers written by PhD students are read and extensively discussed with at least one of the two professors of the group. Each PhD student is expected to publish at least 5 papers in good conferences to form the basis of the PhD thesis. Several of our past PhD students have exceeded this requirement by a large margin.

Some members of staff are more interested in teaching, whereas others are more research oriented. This preference is reflected to an extent in the distribution of the work load. However, all members of academic staff are involved in teaching and research. Over the past three years DIES has organised the weekly embedded systems seminars with attendance from CAES and others, which we believe provides staff and students with an opportunity to broaden their horizon.

## 5. Academic reputation (we mention highlights only, omitting PC membership etc)

### Prof Dr. Pieter Hartel

- Co-initiator of the national STW Sentinels program
- Coordinator of a new major national research initiative "Veilig Internet"
- Chair of the IFIP WG 8.8 on smart cards from 2000-2004
- Invited talk Int. Workshop Construction and Analysis of Safe, Secure and Interoperable Smart cards (CASSIS), March 10-14, 2004, Marseille, France
- Keynote 6th Int. Workshop on Issues in the Theory of Security (WITS) March 25-26 2006, Vienna, Austria

*Dr. Sandro Etalle*

- Coordinator for Twente of the Kerckhoffs National Master Course in ICT Security
- Co-founder of the Nationaal samenwerkingsVerband Security Onderzoek (NVSO)
- Program chair of the 22nd Int. Conf. on Logic Programming, Seattle, August 17 - 20, 2006
- Vice-chair of IFIP WG 11.11 on Trust Management

**6. External validation*****6.a. Societal relevance***

We target our work at a variety of applications, ranging from smart guns, via smart surroundings to smart homes and smart vehicles. The smartness in each case refers to a specific property of the application that improves the application beyond what is possible today. In our smart home we facilitate near-zero configuration. This allows users to bring in new appliances that integrate with the installed home automation system, seamlessly and securely. A smart gun is smart because it will recognise the rightful owner. This means that if a gun is lost, stolen or wrestled out of the hands of the owner, it will simply refuse to fire. Our surroundings are smart when they anticipate on, and contribute to the activities of the people in these surroundings. For example, when sensors in a building can detect changes in environmental conditions such as temperature, and humidity to which the system can react adequately.

Our network intrusion detection tools are currently being field tested by customers of one of our sponsors. We hope that this will lead to widespread deployment of one of our innovations. Our real time scheduling methods have been implemented in a commercially available product from Ambient Systems called AmbientRT.

***6.b. Industrial contacts***

- Local: Ambient Systems; Livio; Roessingh R&D; TI-WMC; Telematica Instituut; Twente Solid State Technology.
- National: Almende BV (Rotterdam); Belastingdienst (Apeldoorn); Chess (Haarlem); Ernst & Young (Rotterdam); FOX-IT (Pijnacker); Korps Landelijke Politiediensten (Apeldoorn); Logica CMG (Amstelveen); Nedap (Groenlo); Oce (Venlo); Philips Research (Eindhoven); Rabo Bank (Utrecht); Siemens (Den Haag); Thales (DECIS Lab, Delft); TNO (Delft); TPG Post (Den Haag).
- International: Axalto (Louviciennes, Fr) ; Bell Labs (Murray Hill, NJ, USA) ; Carl Walther GmbH (Ulm, De); FN HERSTAL, SA (Herstal, Be); Gemplus (La Ciotat, Fr) ; Heckler & Koch GmbH (Oberndorf/Neckar, De); KPMG (Milano, It) ; Nokia Research (Espoo, Fi); Telecom Italia (Torino, It); Telefonica (Madrid, Es); Telindus (Heverlee, Be); Trialog (Paris, Fr); WRAP/Indesit (It).

## 7. Researchers and other personnel ("wp")

Table 4

Name and present title		2003	2004	2005
professor (hgl)	Hartel, Prof.dr. P.H.	0,4	0,4	0,4
associate professor (uhd)	Jansen, Ir. P.G.	0,4	0,4	0,4
	Schoute, Dr. A.L.	0,4	0,32	0,32
assistant professor (ud)	Etalle, Dr. S.	0,38	0,38	0,4
	Scholten, ir. J.	0,4	0,4	0,4
	Vervoort, Ir. W.A.	0,2	0,2	0,18
<b>Total tenured staff</b>		<b>2,18</b>	<b>2,1</b>	<b>2,1</b>
professor (hgl)	Michiels, Prof.ir. E.F.	0,04	0,09	0,03
	Mullender, Prof.dr. S.J.	0,09	0,09	0,09
assistant professor (ud)	Doumen, dr. J.M.			0,12
	Mader, dr. A.H.	0,09	0,34	0,34
postdoctoral fellows	Cederquist, dr. J.G.		0,25	1,0
	Dijk, dr.ir. H.W. van			0,8
	Doumen, dr. J.M.	0,3	1,0	0,7
	Hartog, dr. J.I. den		0,75	1,0
	Lijding, dr. M.E.M.	0,84	0,42	0,5
	Mader, dr. A.H.	0,63		
	Zwaag, Ir. B.J. van der			0,5
	Bolzoni, D.			0,4
junior staff (aio, oio, moz-p)	Brinkman, R.	0,7	0,8	0,8
	Buhan, I.R.		0,13	0,8
	Chong, C.N.	0,8	0,8	0,2
	Corin, R.J.	0,8	0,8	0,8
	Czenko, M.R.		0,13	0,8
	Durmaz, O.			0,73
	Hanssen, Ir. F.T.Y.	1,0	0,66	0,84
	Kavaldjiev, N.K.	0,8	0,8	0,8
	Kaya, O.S.		0,2	0,49
	Khatib, M.G.		0,03	0,4
	Law, Y.W.	0,8	0,8	0,75
	Lenzini, G.	0,2	0,8	
	Lijding, dr. M.E.M.	0,16		
	Marin Perianu, R.S.		0,13	0,8
	Saptawijaya, A.		0,07	0,66
	Staicu, I.		0,39	
	Sundramoorthy, V.	0,8	0,8	0,8
	Tran, H.M.			0,8
other junior staff (moz, twaio)	Rosien, Ir. M.A.J.	0,46		
<b>Total non-tenured staff</b>		<b>8,51</b>	<b>10,27</b>	<b>15,95</b>
<b>Total Research staff DIES</b>		<b>10,69</b>	<b>12,38</b>	<b>18,05</b>

## 8. Resources, funding and facilities

### 8.a. Laboratory infrastructure

We have excellent lab facilities in which we co-operate with several other groups. All the lab facilities will be integrated in the Smart Environments lab which is currently being set up in the context of the 3TU/NIRICT.

**8.b. FTE-funding PhDs/postdocs***Table 5*

<i>Funding</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>Average</i>
Direct funding	4%	12%	18%	11%
Research funds	46%	29%	39%	38%
Contracts	50%	58%	43%	50%
Other	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

**8.c. List of external funds***Table 6*

<i>Name project</i>	<i>Start date</i>	<i>End date</i>	<i>Sponsor</i>
AMETIST: Advanced Methods for Timed Systems	1-4-2002	1-7-2005	European Commision
AMSD: Accompanying Measure on System Dependability	1-6-2002	1-6-2003	European Commision
ARTIST-2: Network of Excellence on Embedded Systems Design	1-10-2004	1-10-2008	European Commision
CaberNet: Network of Excellence in Distributed and Dependable Computing Systems	1-1-1996	1-1-2004	European Commision
EYES: Energy-Efficient Sensor Networks	1-3-2002	1-3-2005	European Commision
Inspired: Integrated Secure Platform for Interactive Personal Devices	1-12-2003	31-12-2006	European Commision
RESET: Roadmaps for European research on Smartcard related Technologies	1-9-2002	1-5-2003	European Commision
TEAHA: The European Application Home Alliance	1-1-2004	1-1-2007	European Commision
MoMS: Methods of Modelling Embedded Systems	1-1-2003	1-1-2007	NWO Meervoud
@HA: @ Home Anywhere	1-11-2001	1-7-2006	NWO Open Competition
Account: Accountability in Electronic Commerce Protocols	1-10-2004	1-10-2006	NWO Open Competition
AMIS: Advanced Multimedia Indexing and Searching	1-7-1997	1-5-2003	NWO Open Competition
Gecko: Communication and Scheduling in Reconfigurable Multimedia	15-6-2002	15-6-2006	NWO Open Competition
MOCA: Modeling Control Aspects of Embedded Systems	1-5-2005	1-9-2009	NWO Open Competition
Secure Meta Data: Secure Content Management In Ambient Environments	1-2-2003	1-2-2007	Philips Electronics
SIRE: Security Incident Response Establishment	1-6-2002	1-6-2006	Rabobank
BRICKS/PDC1: Security, Identification and Authentication	1-1-2004	1-1-2009	SENER / BSIK
Freeband/I-share: Sharing resources in virtual communities for storage, communications, and processing of multimedia data	1-1-2004	1-1-2009	SENER / BSIK
Smart Surroundings	1-4-2004	1-10-2008	SENER / BSIK
PAW: Privacy in an Ambient World	1-10-2003	1-10-2007	SENER IOP GenCom
A4: Adaptive non-volatile storAge systems for Adaptive Applications	1-10-2004	1-12-2008	STW Open Competition
Chameleon: Reconfigurable computing in hand-held multimedia computers	1-12-1999	31-12-2004	STW Open Competition
Secure Grip	1-11-2004	1-11-2008	STW Open Competition
IPID: Integrated Policy-based Intrusion Detection	1-7-2005	1-7-2009	STW Sentinels
PINPASJC: Program Inferred Power Analysis in Software -- JavaCard	1-1-2005	1-12-2008	STW Sentinels

<i>Name project</i>	<i>Start date</i>	<i>End date</i>	<i>Sponsor</i>
LicenseScript: A language and framework for calculating licenses on information over constrained domains	1-10-2002	31-12-2004	Telematica Instituut
MESEC: Mobile Enabled Secure Exchange of Content	19-4-2004	30-4-2005	Telematica Instituut

## 9. Overview of the results

### 9.a. Description of scientific results

The recent results that we are most proud of are:

- Several extensions of the Dolev Yao model with tool support to verify security protocols subject to more versatile attackers [Thesis Corin].
- A step towards an integrated theory of dependability and security [Thesis Lenzini].
- A detailed understanding of the mechanisms available to attack and to defend all common MAC protocols used in WSN [Thesis Law].
- A characterisation of the seven principles of service discovery [Thesis Sundramoorthy].
- A range of methods to support searching in encrypted data [Thesis Brinkman].

### 9.b. Key publications

Table 7

<i>nr</i>	<i>Title</i>
1	Bosch, P. and Mullender, S.J. and Narlikar, G.J. and Samuel, L.G. and Yagati, L.N. (2006) <i>Integrated base stations and a method of transmitting data units in a communications system for mobile devices</i> . Patent Application US20060171364. Lucent Technologies, Inc.
2	Corin, R.J. and Saptawijaya, A. and Etalle, S. (2006) <i>A Logic for Constraint-based Security Protocol Analysis</i> . In: IEEE Symposium on Security and Privacy, 21-25 May 2006, Oakland, US. pp. 155-168. IEEE Computer Society Press. ISBN 0-7695-2574-1
3	Kalker, T. and Epema, D.H.J. and Hartel, P.H. and Lagendijk, R.L. and van Steen, M. (2004) <i>Music2Share - Copyright-Compliant Music Sharing in P2P Systems (Invited paper)</i> . Proceedings of the IEEE, Special Issue on Digital Rights Management, 92(6):961-970. ISSN 0018-9219
4	Law, Y.W. and Doumen, J.M. and Hartel, P.H. (2006) <i>Survey and Benchmark of Block Ciphers for Wireless Sensor Networks</i> . ACM Transactions on Sensor Networks, 2(1):65-93. ISSN 1550-4859
5	Sundramoorthy, V. and Tan, C. and Hartel, P.H. and den Hartog, J.I. and Scholten, J. (2005) <i>Functional Principles of Registry-based Service Discovery</i> . In: 30th Annual IEEE Conf. on Local Computer Networks (LCN), Sydney, Australia. pp. 209-217. IEEE Computer Society Press. ISBN 0-7695-2421-4



**9.c. Numerical overview of the results in a fixed format of categories***Table 8*

		2003	2004	2005
1 Academic publications	a. PhD-theses	2		3
	b. in refereed journals	2	4	5
	c. international conference proceedings	21	26	27
	d. books			
	e. book -chapters		2	
<b>Total</b>		25	32	35
2. International patents		1	1	

**9.d. Full outcome list****2003***PhD-theses*

- Benz, H.P. Casual Multimedia Process Annotations--CoMPAs. (2003, mei 14). 194 pp. Thesis advisor(s): Prof.dr. P.H. Hartel, Dr. G. van der Veer. ISBN: 90-365-1892-X
- Lijding, M.E.M. Real-Time Scheduling of Tertiary Storage. (2003, mei 1). 225 pp. Thesis advisor(s): , Dr. D.L. Pressotto. ISBN: 90-365-1890-3

*Journal articles*

- Brinksma, H. , Mader, A.H. Prozessalgebra, Teil 1. Automatisierungstechnik nr: 8, 51, (2003). 4 pp. ISSN: 0178-2312
- Brinksma, H. , Mader, A.H. Prozessalgebra, Teil 2. Automatisierungstechnik nr: 9, 51, (2003). 4 pp. ISSN: 0178-2312

*Conference proceedings*

- Bistarelli, S. , Cervesato, I., Lenzini, G., Martinelli, F. Relating Process Algebras and Multiset Rewriting for Immediate Decryption Protocols. 2nd Int. Workshop on Mathematical Methods, Models and Architectures for Computer Networks Security (2003). (pp. 86-99) St.Petersburg Rusland Springer-Verlag Berlijn ISBN: 3-540-40797-9
- Chong, C.N. , Corin, R.J., Etalle, S., Hartel, P.H., Jonker, W. LicenseScript: A Novel Digital Rights Language and its Semantics. 3rd Int. Conf. on Web Delivering of Music (2003). (pp. 122-129) Leeds, United Kingdom IEEE Computer Society Press, Los Alamitos, California ISBN: 0-7695-1935-0
- Chong, C.N. , Corin, R.J., Etalle, S., Hartel, P.H., Law, Y.W. LicenseScript: A Novel Digital Rights Language. IFIP TC6 WG6.11 Int. Workshop for Technology, Economy, Social and Legal Aspects of Virtual Goods (2003). (pp. 104-115) Ilmenau, Germany Technical University Ilmenau, Germany ISBN: not assigned
- Chong, C.N. , Etalle, S., Hartel, P.H. Comparing Logic-based and XML-based Rights Expression Languages. Confederated Int. Workshops: On The Move to Meaningful Internet Systems (2003). (pp. 779-792) Catania, Sicily, Italy Springer-Verlag, Berlin ISBN: 3-540-20494-6
- Chong, C.N. , Etalle, S., Hartel, P.H., Law, Y.W. Approximating Fair Use in LicenseScript. 6th Int. Conf. of Asian Digital Libraries (2003). (pp. 432-443) Kuala Lumpur, Malaysia Springer-Verlag, Berlin ISBN: 3-540-20608-6
- Chong, C.N. , Peng, Z., Hartel, P.H. Secure Audit Logging with Tamper-Resistant Hardware. 18th IFIP TC11 Int. Conf. on Information Security, Security and Privacy in the Age of Uncertainty (2003). (pp. 73-84) Athens, Greece Kluwer Academic Publishers Boston ISBN: 1-4020-7449-2
- Corin, R.J. , Durante, A., Etalle, S., Hartel, P.H. A Trace Logic for Local Security Properties. Proceedings of the International Workshop on Software Verification and Validation (SVV

- 2003) Electronic notes in theoretical computer science 118, (2003, december 14 / 2003, december 14). (pp. 129-143) Elsevier ISSN: 1571-0661
- Corin, R.J. , Malladi, S., Alves-Foss, J., Etalle, S. Guess what? Here is a new tool that finds some new guessing attacks. IFIP WG 1.7 and ACM SIGPLAN Workshop on Issues in the Theory of Security (2003). (pp. 62-71) Warsaw, Poland Dpt. di Scienze dell'Informazione Universita di Bologna ISBN: not assigned
- Di Pietro, R. , Mancini, L.V., Law, Y.W., Etalle, S. LKHW: A Directed Diffusion-Based Secure Multicast Scheme for Wireless Sensor Networks. 32nd Int. Conf. on Parallel Processing Workshops (2003). (pp. 397-406) Kaohsiung, Taiwan IEEE Computer Society Press, Los Alamitos, California, ISBN: 0-7695-2018-9
- Dillema, F.W. , Stabell-Kulo, T. Pesto flavoured security. 22nd Symp. on Reliable Distributed Systems (2003). (pp. 241-249) Florence, Italy IEEE Computer Society Press Los Alamitos, California ISBN: 0-7695-1955-5
- Gnesi, S. , Lenzini, G., Martinelli, F. Logical Characterization and Analysis of Fault Tolerant Systems through Partial Model Checking. Proceedings of the International Workshop on Software Verification and Validation (SVV 2003), December 14 2003, Mumbai, India Electronic notes in theoretical computer science 118, (2003, december 14 / 2003, december 14). (pp. 57-70) Elsevier ISSN: 1571-0661
- Hanssen, F.T.Y. , van den Boom, J., Jansen, P.G., Scholten, J. Time synchronization for an Ethernet-based real-time token network. 2nd Int. Workshop on Real-Time LANs in the Internet Age (2003). (pp. 71-74) Porto, Portugal Polytechnic Institute of Porto, Portugal ISBN: 972-8688-12-1
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## 10.SWOT-analysis (excluding SWOT items already mentioned in part A)

### *Strengths*

- Ability to attract external funding.
- Many and strong industrial contacts.

### *Opportunities*

- Security and dependability are hot topics, which will lead to new applications in for example health and well being.
- Valorisation of security tools

